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Future Seabasing Technology Analysis: Logistics Command and Control

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14. ABSTRACT
The Center for Naval Analyses (CNA) was tasked by the Office of Naval Research (ONR) to review the Navy's seabasing concept, identify potential operational problems and propose science and technology (S&T) investments to produce new technologies or significantly improve existing ones. Formulation of such S&T recommendations requires clear definition of the concept and operational construct of the sea base. We began with a review of the literature that describes the sea base and the technologies that must be developed to make it possible. We supplemented the literature review with discussions with experts in the area of seabasing. We examined the composition of the sea base as a function of the type and scope of the contingencies that were addressed by the seabased forces and determined that all seabasing operations, large or small, required a common set of operational capabilities. The needed capabilities can be grouped into three categories

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Executive summary

The Center for Naval Analyses (CNA) was tasked by the Office of Naval Research (ONR) to review the Navy's seabasing concept, identify potential operational problems and propose science and technology (S&T) investments to produce new technologies or significantly improve existing ones. Formulation of such S&T recommendations requires clear definition of the concept and operational construct of the sea base. We began with a review of the literature that describes the sea base and the technologies that must be developed to make it possible. We supplemented the literature review with discussions with experts in the area of seabasing. We examined the composition of the sea base as a function of the type and scope of the contingencies that were addressed by the seabased forces and determined that all seabasing operations, large or small, required a common set of operational capabilities. The needed capabilities can be grouped into three categories:

- Logistics systems
- Connectors
- Logistics command and control (C2).

We analyzed each of these categories of capabilities. In this report, we address logistics command and control. Analyses of the other categories are reported separately [1,2].

The logistics management of the sea base will require a system that is fundamentally different from the logistics system now in place. It will have enhanced capability and much greater capacity because the logistics flow will be greater and detailed information about logistics must be available in real time for planning and operational purposes. The C2 system will be consistent with the Navy's vision of embracing network-centric warfare and will emphasize new types of information gathering and utilization. It should be based on the concepts of Sense

and Respond Logistics. Sense and Respond Logistics is defined as a network-centric, adaptable logistics system that can respond quickly to the unpredictabillity of demand.

A prototype for the operational system—Distributive Collaborative Command and Control (DCC2)—is being developed now. This program aims to develop a fielded FORCEnet C2 capability that provides actionable logistics information to decision makers at the speed of battle. We believe that DCC2 can serve as the framework for development of a workable logistics C2 system in the 2015–2020 time frame.

The development of the C2 system for the sea base will be technically challenging. In the longer term, several S&T areas should be investigated:

- Intelligent agents - software based decision aids that assist the decision makers in developing and choosing courses of action
- Bandwidth supply - a determination of whether sufficient bandwidth will be available for the transfer of the large amounts of logistics data
- Quantum cryptography - an unbreakable method of ensuring data security.

Literature review

There is a rich body of literature on seabasing. The documents include descriptions of the seabasing concept and analyses by a number of groups on the challenges that must be overcome to make the system work. There is also a report of analyses by the Naval Postgraduate School (NPS) that measure the projected performance of several 2015 sea base concepts against the top-level measures of performance (MOP) or the sea base requirements.

Seabasing Joint Integrating Concept (JIC)

The seminal work on seabasing is the Seabasing Joint Integrating Concept (JIC)[3] issued in 2005 and approved by the Joint Requirements Oversight Council (JROC). This document outlines the concept of seabasing as it will be employed in the 2015 to 2025 time frame. Seabasing is defined as the rapid deployment, assembly, command, projection, reconstitution and re-employment of joint combat power from the sea, while providing continuous support, sustainment, and force protection to select expeditionary joint forces without reliance on land bases within the joint operations area (JOA). These capabilities expand operational maneuver options and facilitate assured access and entry from the sea. The Seabasing JIC distills the seabasing capabilities into five lines of operation and associates a top-level MOP with each phase. These phases and their associated MOPs are listed below:

- CLOSE - Close joint sea based capabilities, including elements of command and control (C2), to a JOA to support major combat operations within 10–14 days of execution order
- ASSEMBLE - Assemble and integrate joint capabilities from the sea base to support major combat operations within 24–72 hours of arrival within the JOA

- EMPLOY - Employ over the horizon from the sea base at least one brigade for joint forcible entry operations (JFEO) within a period of darkness (8–10 hours)

- SUSTAIN - Sustain joint seabased operations, including at least two joint brigades operating ashore, for an indefinite period using secure advanced bases up to 2000 n.mi. away; also support selected joint maintenance and provide level III medical care within the sea base

- RECONSTITUTE - Reconstitute one brigade from ashore to the sea base and reemploy within 10–14 days of execution order.

The purpose of seabasing is to allow the military to operate independently without the support of other countries. In an era in which basing rights in other countries may be difficult to secure, seabasing affords the United States the ability to operate without such rights, to conduct its operations purely from the sea. Force commanders need to be able to project power to respond to emerging crises when forward basing may not be available or the use of such bases may be politically undesirable. Seabasing offers this flexibility and will be an increasingly critical capability in the future. Action through a sea base will allow forces to be assembled quickly independently of political constraints, employed from the sea base, and supported indefinitely from the sea base. If necessary, forces can be withdrawn and reconstituted for additional employment within the JOA or in other areas where they may be required.

According to the JIC, the sea base is defined as an inherently maneuverable, scalable aggregation of distributed, networked platforms and organizations, capable of receiving deploying forces and supporting the employment of those forces. It is not merely a collection of ships. The size and composition of the sea base will vary with the type of contigency to which it is responding. The JIC enumerates seven overarching principles of seabasing:

1. Use the sea as a maneuver space

2. Leverage forward presence and joint interdependence

3. Protect joint force operations
4. Provide scalable, responsive joint power projection
5. Sustain joint force operations from the sea
6. Expand access options and reduce dependence on land bases
7. Create uncertainty for adversaries.

The JIC includes, in a classified annex, a set of scenarios that illustrate the sets of forces and the concept(s) of operations (CONOPS) that are used. These scenarios include humanitarian assistance/disaster relief (HA/DR) operations, counterinsurgency operations (COIN), and major combat operations (MCO). These scenarios are illustrative of some of the situations in which a sea base can be used to respond to a contingency.

Defense Science Board Task Force

At the request of the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, a Task Force of the Defense Science Board (DSB) examined "how seabasing of expeditionary forces can best serve the nation's defense needs through at least the first half of the 21st century" [4]. Specifically, the task force considered operational requirements, required assets, the role of new technologies and the effects of jointness. It concluded that seabasing is a critical capability for the United States, especially if there is a need to undertake forcible entry operations. Although some precursor amphibious capabilities are presently in place, such a seabasing capability does not now exist. Concentrating on the role of the sea base, the study identified many of the new capabilities that must be developed to make seabasing a reality.

The study identified 12 critical issues, referred to as the dirty dozen, that must be addressed in the development of seabasing. One chief recommendation of the DSB Task Force is the establishment of a joint program office to manage sea base development. Such an organization is needed for the complex effort of planning the development of the platform pieces (ships, aircraft, cargo handling systems, logistics management systems, communications) and their coordination and

integration into an interoperable, coherent whole. Of the list of capabilities that must be developed, the task force identified three that stand out as particularly important:

- Improved cargo handling capabilities that can operate in rough seas
- Long-range heavy lift aircraft that can be based at sea
- Next generation ships that support seabasing requirements.

The cargo handling capabilities include movement within a single ship and between ships of both similar and different sizes at sea states up to sea state 4. The heavy lift aircraft need a capacity of 20 tons and the ability to interface with the sea base. The suggestion to develop ships of appropriate design may have been overtaken by events. The Navy recommendation for the Maritime Prepositioning Force (Future) (MPF(F)) is to adopt a family-of-ships concept in which the MPF(F) squadron is primarily composed of vessels already designed and in production, perhaps with some modifications.

Naval Research Advisory Committee

The Assistant Secretary of the Navy (Research, Development and Acquisition) (ASN RD&A) asked the Naval Research Advisory Committee (NRAC) to examine an operation involving the closing of a Marine Expeditionary Brigade (MEB) through sea state 4 with an emphasis on the connectors from the advanced base (AB) to the sea base and thence onward to the shore objectives. The committee's purpose was to identify the technology developments necessary to achieve the desired capability in both the near-term and the long-term. They reported to ASN RD&A in August 2004 [5]. They found that a critical core function for the sea base is end-to-end material transport, which will require high throughput and reliability and standardized containers. A critical enabler for the sea base is a high speed surface connector to operate in sea state 4 with fast loading and unloading and reduced fuel usage. Advances in the landing craft, air cushioned (LCAC) and LCAC loading procedures may provide the surface connector, and the high speed connector (HSC) can act as an LCAC truck to increase the standoff range for surface assault. There

is also a capability gap with respect to air connectors. The NRAC members recommend continuing with development of the CH-53X (recently renamed the CH-53K) helicopter and supporting the Joint Heavy Lift Task Force, which is a longer term option. The NRAC group also had considerable concern about the maturity of the plans for building the MPF(F), believing that there needed to be more systems engineering and demonstrations before committing to a plan and building the ships. As an interim step, they recommended conversion of an S-class container ship as a test platform, followed by a spiral development program. This recommendation has also been overtaken by events.

Naval Studies Board

At the request of the Department of the Navy, the Naval Studies Board (NSB) convened a workshop to assess the science and technology base for developing seabasing, specifically addressing CONOPS for seabasing operations, a technology roadmap for cargo handling and heavy lift aircraft, and the issues in creating the sea base as a joint system-of-systems. The workshop focused on the Department of the Navy (DoN) program, and the DSB study addressed the broader needs of the entire Department of Defense (DoD). The workshop was held in September 2004, and the results were published in 2005 [6].

The NSB study found that the level of jointness in the implementation of seabasing will greatly affect the degree to which a new capability is developed rather than how much current capabilities are extended and improved. It reported that full joint integration is the preferred model that will lead to a new, transformational capability. The concept of seabasing must be joint from its conception onward; there will not be as great an effect if the integration is less complete. To assure that this path is followed, the NSB recommended establishment of a Joint Sea Base Planning Office to be headed by a Navy flag officer or a Marine Corps general officer reporting to the Office of the Secretary of Defense. This office should have representatives of all four Services, Special Operations Command, and the United States Transportation Command (USTRANSCOM). It would supervise all necessary studies for the design of the sea base and would guide the experimentation that helps to mature the planning. At the

appropriate time, this office could grow into a joint program office for the sea base.

The NSB workshop reviewed the state of the technology for cargo transfer to the sea base and from the sea base to ship-to-shore connectors. Current capabilities permit some at-sea cargo transfers in benign conditions, but routine transfers of twenty-foot equivalent unit (TEU) shipping containers at high sea states are not currently possible. Adoption of standardized packaging such as the Joint Modular Intermodal Container (JMIC) would immensely simplify the problem. At the time of the report, the workshop concluded that assessment of the technology development needs could not be done in the absence of design plans for the MPF(F) platform(s), which would be the hub of the cargo transfer system, and that the MPF(F) design(s) should not be frozen without consideration of cargo handling. They noted that the time lines for designing the MPF(F) and for developing cargo handling technologies were not synchronized and they spoke of "[v]aguely stated plans ··· for retrofitting or for inserting improved cargo-handling capabilities into current or future MPF(F) hulls." The committee expressed concern over the lack of an integrated research and development (R&D) effort specifically designed to provide high-sea-state cargo-transfer capabilities for MPF(F). They believed that there was a lack of both a sense of urgency and the required funding support. They believed that, without a large-displacement test bed, the enhanced capabilities may not be available for fielding by the Navy in the targeted time line.

The other technology issue that the committee considered was that of a long-range, heavy-lift aircraft. The development of the CH-53X and the MV-22 will improve capabilities, but these aircraft will lack the range, speed, and payload performance to meet the distance and time demands of an assault operation. They concluded that technology should be pursued to develop a ship-capable, fixed-wing aircraft with the cargo capacity of a C-130J. It should be able to operate in a super-short-takeoff and landing (SSTOL) or short-takeoff-and-vertical-landing (STOVL) mode and possibly in full vertical-takeoff-and-landing (VTOL) mode. The committee reviewed several possible technologies that could lead to such an aircraft and made rough estimates of the schedule and cost for the technology development. Such

an aircraft may become operational later than 2025, so it is a long-term development.

The other issue considered by the NSB is an organizational one. They state [6]:

> The lack of an approved overall joint Sea Basing vision and empowered centralized planning authority has resulted in divergent efforts, a lack of clear communication among and within the military Services, and the absence of an effective top-level process or mechanism that might be successful in identifying and enabling a coordinated joint path forward

and further

> [O]ne cannot expect the Services to individually or collectively design the grand scheme of joint integrated Sea Basing absent increased top-down guidance and a centrally managed system-of-systems approach.

The committee enumerates the elements that such a system-of-systems approach must include and the technologies it must encompass. One prong of this approach must be a technologies roadmap that organizes and prioritizes the efforts that must be completed to reach the desired end state of a functional, fully joint sea base. Their main recommendation in this area is the establishment of a Joint Sea Base Planning Office reporting to the Office of the Secretary of Defense. This organizational construct would facilitate the orderly incorporation and spiral development of standardized and complementary new entries and improved design into a project that they recommend naming the "Joint Maritime Prepositioning and Sea Basing Force."

Naval Postgraduate School study

The 2004 Seabasing and Joint Expeditionary Logistics Integrated Project was the effort of the Systems Engineering and Analysis Cohort Six (SEA-6) Team to perform a systems engineering analysis of the 2015 sea base [7]. The SEA-6 team was a group of 50 students and 18 faculty members from different departments at the Naval Postgraduate School. The tasking for the study was provided by the Deputy Chief of Naval Operations for Warfare Requirements and Programs

(OPNAV N7). He directed the team to conduct a study to develop system-of-systems conceptual solutions for seabasing and joint expeditionary logistics (JELo) using current systems, programs of record, and other proposed systems extending over the next 20 years. The SEA-6 team used the Joint Capabilities Integration and Development System (JCIDS) as a framework for the study. After creating a scenario, they tested current (2004) capabilities, a notional 2015 baseline architecture (BLA), and three alternative architectures for the 2025 time frame against the critical operational issues (COIs) for success of the sea base in meeting the time lines arising from the 10/30/30 construct for a brigade-size force performing joint forcible entry operations (JFEO). The BLA uses only those platforms that are currently Programs of Record plus an MPF(F) squadron. The designs for the MPF(F) came from the *Analysis of Alternatives: Final Summary* prepared by the Center for Naval Analyses [8]. This representation of the MPF(F) is different from the one later recommended by the Navy.

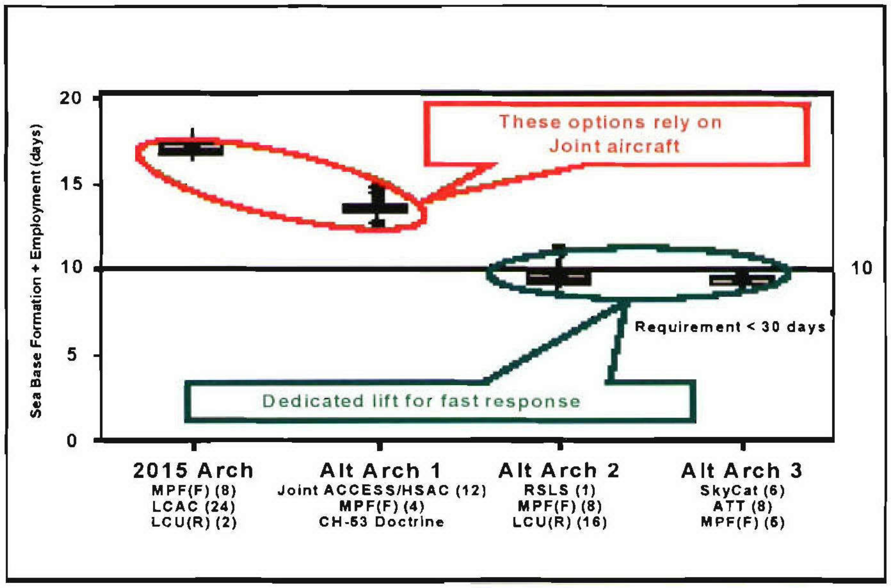
The Alternative Architectures considered by the SEA-6 team differ in design and capabilities from the BLA:

- Alternative Architecture I adopted the Joint Amphibious Combat Cargo Expeditionary Support Ship (Joint ACCESS) High Speed Assault Connector (HSAC) as the primary materiel change from the BLA. The Joint ACCESS is a design for a self-deployable ship primarily used to deliver the two surface battalion landing teams (BLTs) directly from the forward logistics site (FLS) to the beach, thereby replacing the LCACs in the BLA.
- Alternative Architecture II has as its primary materiel changes the use of the rapid strategic lift ship (RSLS) and the landing craft utility, replacement (LCU(R)). The RSLS is a conceptual family of ships that transports the non-self-deploying aircraft (NSDA) to the FLS. The LCU(R)s replace the LCACs.
- The chief change for Alternative Architecture III is in the type of aircraft used and the use of an MPF(F) aviation variant to host the new aircraft. The advanced theater transport (ATT) is a tilt wing version of a C-130-type aircraft with an extremely short takeoff and landing (STOL) capability. This architecture includes more MV-22s and no CH-53s. The proposed heavy lift

airship SkyCat 1000™ [9] is representative of the lighter-than-air technology for use in transporting NSDAs and MV-22s from CONUS to the FLS in Alternative Architecture III.

The results of the study showed that the BLA could not meet the time lines for the 10/30/30 construct. Seizing the initiative within 10 days encompasses the closure, assembly, and employment phases. One chief cause of the failure is the slowness of transport of the NSDAs to the sea base, especially for aircraft that must be disassembled and then reassembled. Time is required for the Air Mobility Command (AMC) to plan, coordinate, and establish an air bridge for the NSDAs and nonprepositioned equipment. This affects the BLA and Alternative Architecture I and causes them to be unable to meet the 10-day time limit. Alternative Architecture II and Alternative Architecture III incorporate strategic lift assets and therefore can meet the required time frames. The results are illustrated in figure 1.

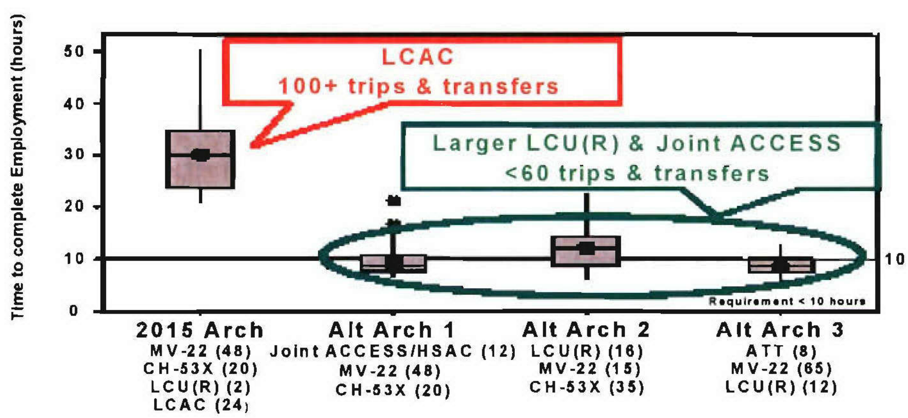
Figure 1. The effect of dedicated lift on the time needed to seize the initiative[a]



a. From [7].

A second constraint on the speed with which the sea base is ready to operate is the number of at-sea transfers needed to employ the forces. If small craft are used to transport troops and equipment, multiple time-consuming transfers must occur. The use of large assault connectors reduces the number of transfers and speeds the process. Each alternative architecture uses large connectors and outperforms the BLA, as shown in figure 2.

Figure 2. The effect of large assault craft on the time needed for employment[a]



a. From [7].

The SEA-6 team reached other conclusions:

- An asset visibility system is critical to avoid excess supplies being stockpiled ashore.
- The MV-22 is better suited to troop transport than to logistics resupply when the mission radius is greater than 150 n.mi.

The study presents a summary of its results as a side-by-side comparison of each of the architectures. It compares the time lines for the architectures to the top-level measures of performance. It also gives an estimated cost for each option. We report these results in table 1.

Each of the alternative architectures performs better than the BLA and does so at a lower cost. Additional analysis would be needed to determine which is the most promising..

Table 1. Summary of the performance of each architecture and its estimated cost

	Closure time (days)	Employment time (hours)	Seize the initiative (days)	Total cost (FY04$B)
BLA	16	30	17	32-42
Alternative 1	13	10	13	28-35
Alternative 2	9	12	10	29-36
Alternative 3	9	9	10	28-35

Other studies

Some other studies have analyzed which technologies are most critical for the efficient operation of the sea base. One by the National Shipbuilding Research Program focused on the strike-up/strike-down (SUSD) process and provided a roadmap to focus and manage technology and system development in that area [10]. Strike-down is the process of receiving material on board a ship, transferring it to its stowage location, and securing it. Strike-up is the inverse process of locating material in its stowage position and moving it to the location where it will be used or transferred off the ship. The report lists 19 specific technology gaps and maps them to future investment recommendations.

The Littoral Warfare Systems Product Area Directors developed an S&T roadmap in support of seabasing capabilities for the 2015 time frame [11]. This document draws on previous analyses to identify needed capabilities and adds those additional capabilities determined in the course of the study. It delineates a set of 18 sea base gaps and needed capabilities. There is a discussion of each gap, the applicable R&D and S&T information, concepts that address the gap, and recommendations on what action to take. The overriding conclusion of the study is that the sea base is a nested system-of-systems and that a systems integration effort should be initiated. The degree to which

each of the gaps has been addressed is assessed and a list of the five main recommendations for action is presented. These recommendations focus on what the authors think must be done to ensure that the various components of the sea base will come to completion and function as an integrated whole.

Taken together, the studies summarized in this section give a comprehensive picture of many of the hurdles that must be cleared for the sea base to begin to function in the 2015–2020 time frame. They lay out some of the gaps that currently exist and suggest paths that may lead to solutions. What is still lacking is an overall quantitative statement of the capabilities that the sea base must have to be considered effective. Both the DSB and the NSB strongly argue that a centralized coordinating body is needed to ensure that all gaps are identified and filled and that the individual programs all come together in a timely fashion to create the new, critical seabasing capability. This central authority does not yet exist.

The seabasing concept

Motivation for seabasing

The United States is currently committed to a transformation of its armed forces. For the Navy, part of this transformation is the adoption of the concept of seabasing. As defined in the JIC [3], seabasing is the rapid deployment, assembly, command, projection, reconstitution and re-employment of joint combat power from the sea, while providing continuous support, sustainment, and force protection to select expeditionary joint forces without reliance on land bases within the joint operations area (JOA). Note that seabasing is defined as a joint concept and the Navy is not the only organization involved in formulating and defining how seabasing will operate.

Part of the motivation for the adoption of the seabasing concept is the uncertainty concerning the future availability of airports and seaports in foreign countries for use by U. S. forces to support operations. Such facilities were available in Kuwait for the support of Operation Iraqi Freedom (OIF), but permission for support was denied by Turkey. It is uncertain in future conflicts whether allies will be predisposed to allow U. S. forces to use their facilities or whether political pressures will cause them to refuse such use. This consideration plays an important role in the decision to adopt the use of seabasing.

Another benefit of the sea base is that it allows joint forces to use the ocean as a maneuver space. Forces can be moved near the area where they will be employed and later repositioned for new operations, thereby enhancing the capability for power projection. This flexibility and maneuverability, which arises from the fact that the platforms can operate in relative safety while at sea, also allow a smaller buildup of logistic support at a single point and eliminate the "Iron Mountain" associated with previous forcible entry operations.

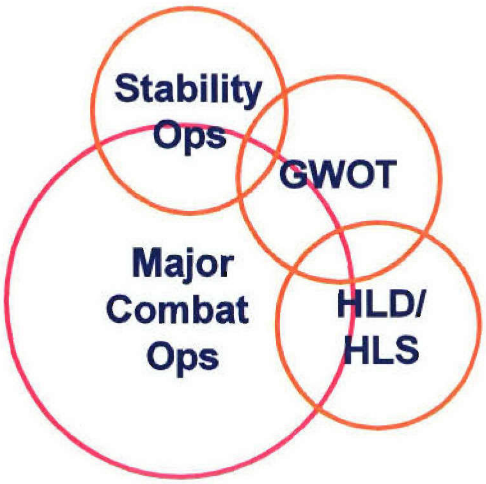
Description of the sea base

A sea base is more than simply a collection of ships operating in the same area. In the JIC [3], a sea base is defined as an inherently maneuverable, scalable aggregation of distributed, networked platforms and organizations, capable of receiving deploying forces and supporting the employment of those forces. Among the purposes that a sea base will serve are the following:

- It will operate without access to air and sea ports.
- It will be capable of inserting and extracting military forces.
- It will be able to sustain those forces ashore from the sea base for weeks or even months.
- It will minimize the land-based logistics footprint.

What ships and other forces will make up a sea base? It will depend on the type and the scope of the contingency for which the sea base is a response. In the post-September 11 world, the Navy has adopted a 3/1 strategy as represented in figure 3.

Figure 3. Representation of the Navy's 3/1 strategy



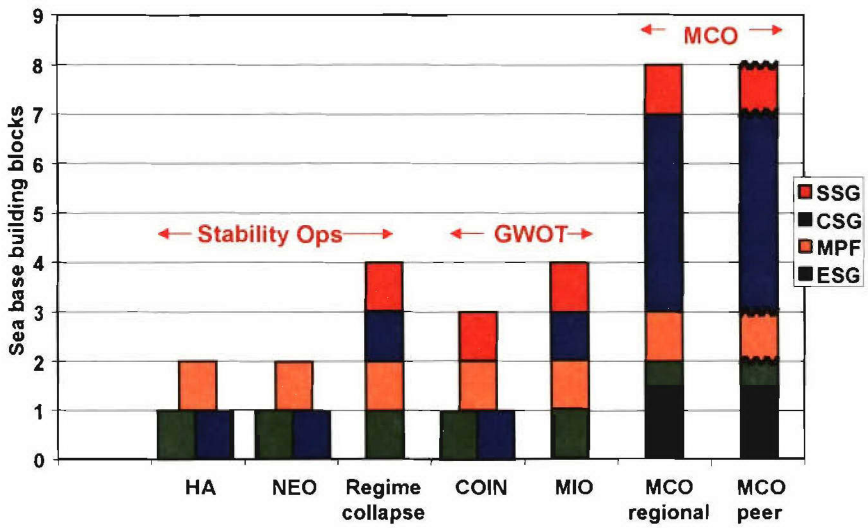
The most important of the tasks to which the Navy must contribute is that of major combat operations. There are three other intersecting but not necessarily encompassed tasks: stability operations, the Global War on Terror (GWOT), and homeland defense/homeland security (HLD/HLS). A contingency requiring a sea base for a response may fall into any of these categories. We have mapped the platforms that could comprise a sea base responding to a contingency. This mapping is not intended to be comprehensive but rather to be illustrative of the magnitude of the sea base that might be needed. Of the categories of contingency, the weakest candidate for seabasing support is that of HLD/HLS. The reason for this is that there is not likely to be a situation within the continental United States (CONUS) for which air and sea ports are not available. Some operations based from the sea have been used in CONUS, for example, disaster relief efforts such as the aid to victims of Hurricane Katrina after it hit the Gulf Coast in August of 2005. The contingencies that we considered were the following:

- Major combat operations
  - — Against a regional competitor
  - — Against a peer competitor
- Stability operations
  - — Humanitarian assistance (HA)
  - — Noncombatant evacuation operations (NEO)
  - — Regime collapse
- Global War on Terror
  - — Counterinsurgency operations (COIN)
  - — Maritime interdiction operations (MIO).

Figure 4 represents an estimate of the Navy units that would contribute to a sea base responding to each of these contingencies. This does not represent the entire composition of the sea base; the joint sea base may contain forces from the other Services and the Coast Guard as well. The sea base platforms are shown as a collection of building blocks that represent deployable units of Navy ships. These units are:

- Surface action group (SAG)
- Carrier strike group (CSG)
- Expeditionary strike group (ESG)
- Maritime prepositioning group (MPG).

Figure 4. Composition of the sea base as a function of contingency



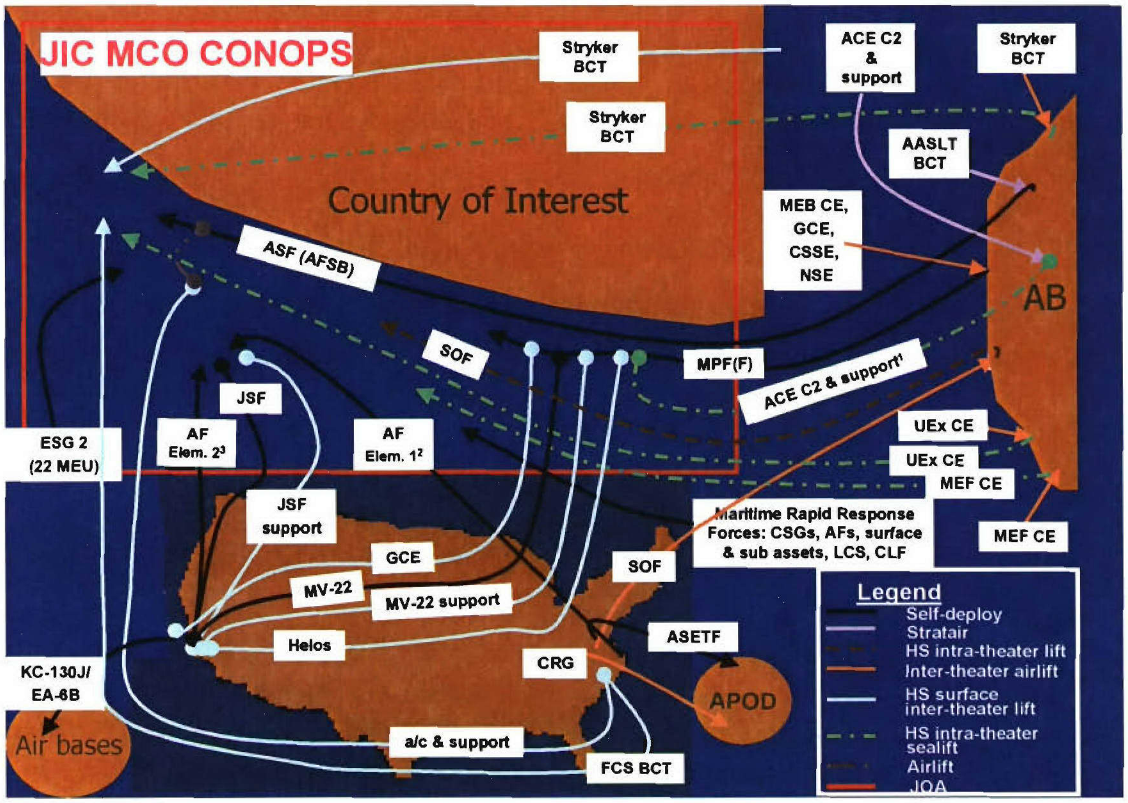
These composition estimates were developed from the scenario CONOPS descriptions in the JIC [3] and from real world experience in events such as the tsunami relief operations in the Indonesia region in January 2005 and NEOs in various countries in the 1990s [12].

Nodes and pathways in the sea base

We examined in some detail the scenarios described in the JIC for HA, COIN, and MCO operations, looking at the force flows that are necessary to assemble and employ the sea base. In particular, we viewed those flows in terms of pathways and nodes. The pathways describe the routes and modes of transportation to move personnel,

equipment, and materials from their initial location to the sea base. Nodes refer to the transfer points of personnel and materials along the pathways. Figure 5 shows a sample diagram illustrating the pathways and nodes for assembling the sea base to support an MCO.

Figure 5. Nodes and pathways for MCO



The figure shows a large number of different units deploying from their initial locations to form the sea base within the JOA, which is outlined in red. Navy units include CSGs, ESGs, SAGs, MPF(F), Littoral Combat Ships (LCS), Combat Logistic Force (CLF) ships, Naval Support Element (NSE) forces, and nuclear powered guided missile submarines (SSGNs). Other units deploy first to the advanced base (AB) and then join the sea base via high speed intratheater lift while it is in transit to the JOA. These units include special operations

forces (SOF) and Army units of employment (UEx), air assault (AASLT) brigade combat teams (BCT), and Stryker BCTs. The Marines also deploy to the AB with Marine Expeditionary Force (MEF) and MEB Command Elements (CE), Ground Combat Elements (GCE), Combat Service Support Elements (CSSE), and Air Combat Elements (ACE). Aircraft such as the Joint Strike Fighter (JSF) and the Marine MV-22s self deploy. Air Force units also deploy from CONUS.

We have constructed similar deployment diagrams for the other types of contingencies with different pathways and modes. Table 2 summarizes the number of pathways and nodes for the three JIC scenarios.

Table 2. Pathways and nodes in JIC scenarios

Scenario	Number of pathways	Number of nodes
HA	20	40
COIN	19	38
MCO	31	62

Note that the number of nodes is twice the number of pathways. Also note that, although the total number of personnel involved in the operations from the sea base is much greater for an MCO than for HA, the number of nodes and pathways for the two scenarios are not so different from one another. This observation leads us to the conclusion that the capabilities needed for operation of the sea base are independent of the size of the sea base. The same functions need to operate in a larger sea base as in a smaller sea base; they just need to handle a greater volume of personnel and material.

Needed capabilities for the sea base

With this conception of the sea base in mind, we reviewed the considerable literature described in an earlier section to extract the most critical capabilities that must exist for the sea base to operate. Our first target date is for the initial operation of the sea base in the latter half of the next decade (currently, initial operational capability

(IOC) is scheduled for 2016 and full operational capability (FOC) is scheduled for 2020) [13]. There have been a number of reviews of the seabasing concept with the aim of identifying those capabilities that will be needed which are not now available. Several of these made recommendations as to the type(s) of ship that should be acquired to make up the MPF(F) [4, 5]. These recommendations are now moot since the Navy has recommended adopting a family of ships design [14]. A single squadron of 14 ships will provide the needed capability. This squadron will be composed of two landing helicopter assault replacement (LHA(R)) with MEB C2, one landing helicopter dock (LHD) with aviation C2, three modified large medium speed roll-on, roll-off (RO-RO) ships (LMSR), three T-AKE variants, three mobile landing platforms (MLP), and two legacy maritime prepositioning force (MPF) dense packed ships.

Another consistent recommendation throughout the reviews is the need for at-sea cargo handling capabilities at high sea states [4,6, 10,11]. There must be the capacity to move cargo from ship to ship in the sea base and to move cargo from ships to connectors to get it ashore. There is also a requirement for the ability to locate and access specific cargo within a ship to enable selective offload of tailored replenishment packages [6,10,11]. Capable intertheater and intratheater connectors are needed to move personnel and materials onto the sea base and from the sea base to the shore. There must be both surface connectors and air connectors. Several of the reviews emphasized the need for heavy lift aircraft that can interface with the sea base [4-6]. As we mentioned earlier, there are several suggested technical paths directed toward this goal.

To tie all these capabilities together and make the sea base function as a coherent whole, there must be an overall C2 system for the sea base. In particular, it must be able to manage the logistics systems.

We have gathered the needed capabilities and grouped them into three categories:

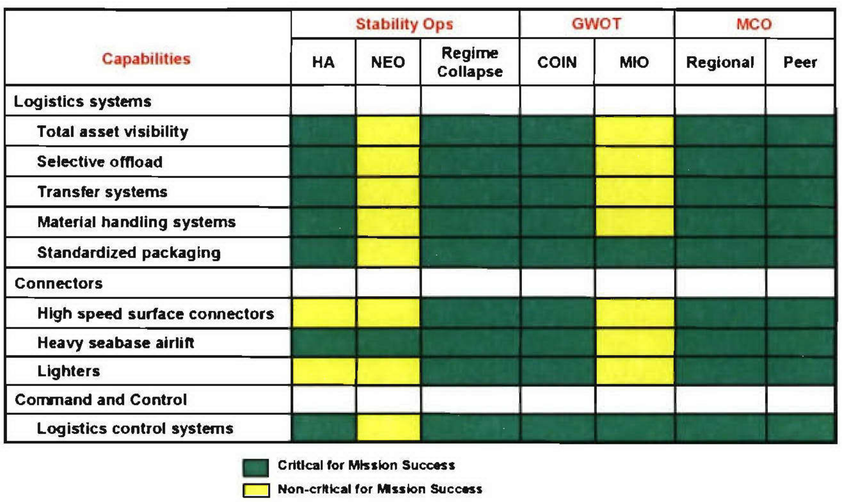
- Logistics systems
  - Total asset visibility

- — Selective offload
- — Material handling systems
- — Standardized packaging

- Connectors
  - — High speed surface (intratheater and intertheater)
  - — Heavy airlift
  - — Material and personnel at-sea transfer systems
- Logistics command and control.

As we said earlier, we believe that these capabilities are general and are independent of the size of the sea base and the type of contingency to which it is responding. The criticality of the various capability may vary from contingency to contingency. Figure 6 illustrates our assessment of how critical each of the capabilities is to the type of contingency considered. The MCOs will require all of the listed capabilities. The NEO requires fewer of them because it is a more tightly focussed operation and may require only aircraft to evacuate those in danger.

Figure 6. Criticality of capabilities for various contingencies



We have divided our analysis of the sea base into three portions, each dealing with one of the categories of capabilities mentioned above. This report covers the issue of logistics command and control. The two other reports deal with logistics systems [1] and connector issues [2].

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Logistics command and control

Requirements for sea base logistics C2

The most important role of the sea base is to employ and sustain up to two brigades of troops ashore. The success of that operation will demand a highly efficient logistics system, especially since there will be no "Iron Mountain" of supplies stockpiled ashore. Current systems are not designed to perform in the high efficiency, high tempo mode that will be required to maintain adequate and timely resupply for the sea base and the supported forces ashore. The current systems lack both capability and capacity to perform this function. The sea base will require a system that operates according to the concept of Sense and Respond Logistics (S&RL).

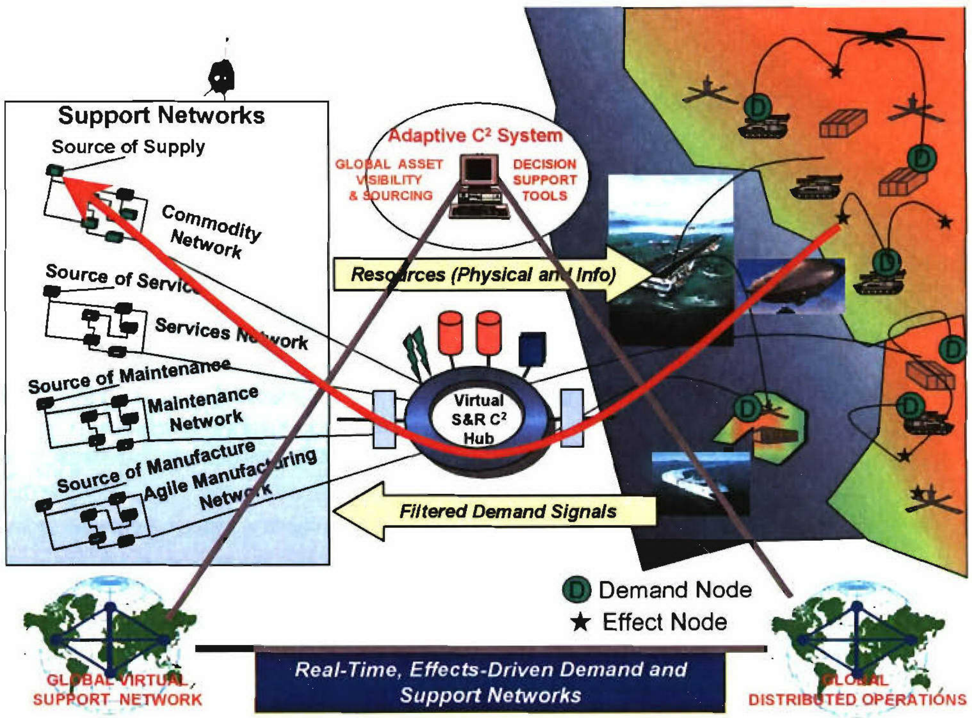
The Office of Force Transformation (OFT) has studied S&RL and begins its discussion of the concept with the following description [15]:

> Sense and Respond Logistics is a transformational, network-centric, knowledge-driven concept that enables Joint effects-based operations and provides precise, agile support. Sense and Respond Logistics relies upon highly adaptive, self-synchronizing, and dynamic physical and functional processes. It predicts, anticipates, and coordinates actions that provide competitive advantage across the full range of military operations. Sense and Respond Logistics promotes doctrinal and organizational transformation, and supports scalable coherence of command and control, operations, logistics, intelligence, surveillance, and reconnaissance.

S&RL replaces the traditional logistics system with a system that can respond to the unpredictably of demand. Current systems are highly optimized and therefore organized to deliver goods in the situation as it is perceived to exist. They are linear in nature and lack flexibility. S&RL uses information technology techniques to sense the situation, determine what the demands are, and adapt to the sensed situation.

Figure 7 is a representation of the S&RL system as it operates from point-of-effect to source of support [16].

Figure 7. S&RL from point-of-effect to source of support



The demand nodes are indicated by the green circles on the right-hand side of the figure; the supply network is to the left. The supply network includes not only the traditional supply chain nodes but also any node capable of supplying the sensed need. In S&RL, all participants can be both providers and consumers of the needed material.

For this to work, there must be total asset visibility (TAV) of everything in the logistics network. This must extend over all organizations, all Services, all agencies, and all coalition partners. Host-nation and opportunistic logistics resources should also be included if possible. It is anticipated that radio frequency identification (RFID) technology devices will be the enabling technology for TAV. Filtered

signals flow from the demand nodes back to the support networks, managed by the S&RL hub. This hub is the virtual crossroads, matching sensed demands with possible sources of supply. The hub will use adaptive strategies to marshall logistics sustainment to support the commander's intent. Decision support tools will allow the hub to function in near real-time. TAV and anticipatory demand based on possible courses of action (COAs) facilitates support of logistics operations and integration of logistics functions with other planning inputs.

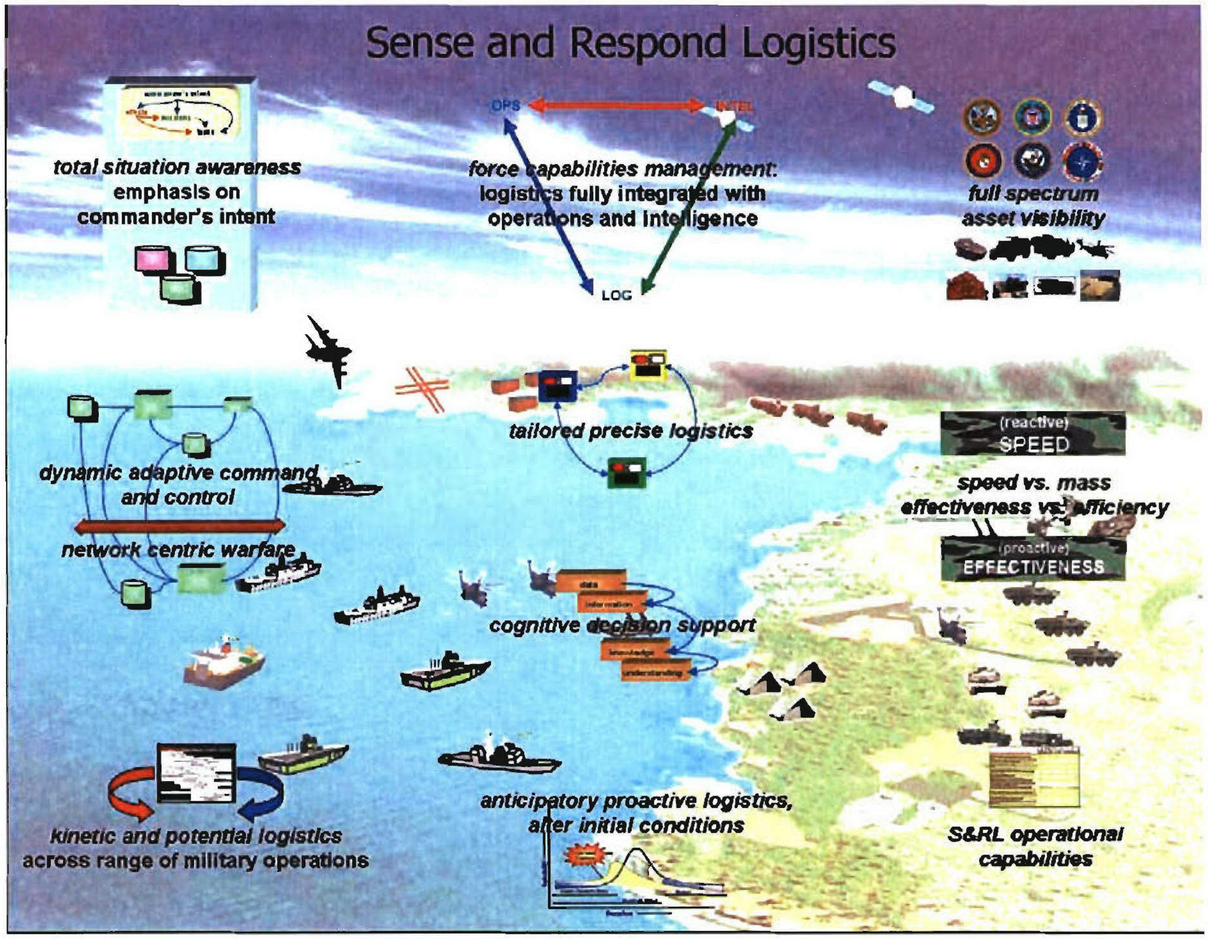
If S&RL is adopted and implemented, the logistics process will be changed in significant ways. One way to capture the effects of S&RL is to compare the characteristics of the logistics systems in their pre-transformational form to what is expected after transformation. Table 3 [15] lists features of the current systems and contrasts those with

Table 3. Logistic systems, pre- and post-transformation

Pre-Transformation	Post-Transformation
Linear	Nonlinear
Chains	Networked, mosaic
Use-based	Effects-based
Service stovepipes	Cross-service mutual support
Functional stovepipes	Cross-enterprise
Title 10-driven	Joint logistics
Preplanned	Dynamic continuous planning and execution
Poor Ops/Log ISR integration	Net Warrior ethos
Reactive	Anticipatory
Parametric analysis-based	Cognitive, knowledge-guided
Hierarchical	Networked, dynamically adaptable
Monolithic	Distributed, modular, adaptable
Poor scalability	Dynamically scalable
Not flexible	Agile, flexible
Consumption-based	Adaptation of evolving commander's intent
Metric: mass	Metric: speed of effect
Metric: efficiency	Metric: effectiveness re: commander's intent
Plan-based	Effects-based
Service perspective	Joint coherence
Globally optimized	Global awareness, local optimization
Brittle, rigid supply chains	Robust, flexible demand networks

what will exist after the implementation is complete. Figure 8 illustrates a sampling of the key concepts for S&RL [15].

Figure 8. Key enabling concepts for S&RL



An S&RL system will make available to all units at all time information about the availability of needed materials and the status of orders to replenish stocks that are running low. With a network-centric environment, forward units can determine when supplies are scheduled to be delivered and adjust their plans accordingly. The support network will be dynamic and will be able to handle both predictable, repeated needs such as Class 1 and unexpected needs such as repair

parts for a particular piece of equipment. The speed of the network will reduce or eliminate the operational pause (the wait for logistics supplies to be built up before exploiting an advantageous situation) that has previously characterized operations such as amphibious assaults.

The S&RL system will incorporate capabilities that do not exist in the current logistics system. As as example, consider total asset visibility (TAV). TAV is the ability to know what is in inventory and where it is stored and to be able to access this information in real time for the entire stock of the sea base and the logistics trains that supply it. Currently, the Navy's inventory records are prepared manually or with the aid of somewhat low tech equipment such as bar code readers and are stored either in paper-based systems or in individual, isolated logistics systems. This type of functionality will not suffice for the sea base of the next decade and beyond.

The logistics systems that manage C2 for the sea base must be consistent with the Navy's transformation to a network-centric force. Network-centric warfare (NCW) is a new military doctrine pioneered by the United States that aims to exploit technical advances in information technology and communications to improve situational awareness and the speed of decision-making [17]. Speed as supplied by improvements in information technology is a key enabler of this transformation and the logistics C2 systems must exemplify this characteristic. Logistics must also become a major component of operational planning. While deciding what course of action to adopt, the commander must have access to the information about what materials and equipment can be supplied to the warfighters in a timely manner. This incorporation of logistics information into the planning process will require a major revamping of the logistics C2 systems to make this information easily available, not a mere tweaking of today's systems to operate in a slightly faster and more efficient mode.

The evolving logistics C2 systems that are consistent with NCW must be GIG-compatible systems. FORCEnet is the glue that binds the three pillars of Seapower 21 (Sea Strike, Sea Shield and Seabasing) [18]. FORCEnet is defined as [19]

> the operational construct and architectural framework for naval warfare in the Information Age that integrates warriors, sensors, networks, command and control, platforms, and weapons into a networked, distributed combat force, scalable across the spectrum of conflict from seabed to space and sea to land.

FORCEnet is the Naval component of the Global Information Grid (GIG). The GIG is the physical manifestation of the NCW doctrine and is defined as the globally interconnected, end-to-end set of information capabilities, associated processes, and personnel for collecting, processing, storing, disseminating, and managing information on demand to warfighters, policy makers, and support personnel [20].

Current logistics systems

The Navy currently has a C2 network that consists of an agglomeration of many different systems. Some of the legacy systems that currently are functioning and will be subsumed or replaced by the sea based C2 system are listed in table 4. We do not consider all portions

Table 4. Current Navy logistics systems

Acronym	System
CASREP	Casualty Report
DAAS	Defense Automated Addressing System
GCCS-M	Global Command and Control System - Maritime
GCSS	Global Combat Support System
GSORTS	Global Status of Resources and Training System
GTN	Global Transportation Network
JMPS	Joint Mission Planning System
JOPES	Joint Operation Planning and Execution System
NAVMACS II	Naval Modular Automated Communications System
NSOF	Navy Status of Forces
NTCSS	Naval Tactical Command Support System
SORTS	Status of Resources and Training System
TRMS	Type Commander Readiness Management System
WebSked	Web-based Scheduling

of the C2 system (for instance, we do not consider operational C2) but will focus on logistics C2.

USMC logistics systems

Since the sea base will be a joint Service operation, the C2 system must be able to interface not only with current Navy systems, but also with the systems of other Services. In particular, the C2 systems for the Navy and the United States Marine Corps (USMC) must be compatible, since those two Services will be working together in most seabasing operations. The Marines have recently revamped their logistics systems to create the Common Logistics Command and Control System (CLC2S). This is a tactical web-enabled logistic information system that arose from an ONR Future Naval Capability (FNC) program[21]. CLC2S 2.0 transitioned to the USMC by February 2004 and supports the Marine Air Ground Task Force (MAGTF) by performing the following functions:

- Joins logistics C2 functions in an interoperable system aiding operational and tactical level logistics.
- Supports mission analysis and orders/course of action (COA) development.
- Monitors Combat Service Support (CSS) function execution.
- Deploys to lower command echelons for asynchronous communication if available bandwidth cannot support synchronous reachback to the CLC2S website.
- Gives sustained and responsive logistics information regardless of tactical situation.
- Enables Seapower 21 by giving planners and operators access to information for supporting operational objectives.
- Provides coherent information even if data sets are in physically separate heterogeneous databases. This allows logisticians to tailor data and manipulate information, which reduces response times and aids precision of logistics planning and execution. CLC2S is accessible via existing tactical, operational and strategic communications networks.

The CLC2S software combines three core capabilities:

- Rapid Request Tracking System (RRTS) - Requesting items and checking on status of previous requests.
- Enhanced Combat Service Support Operations Center (CSSOC) System (ECS) - Asset management.
- Logistics Planning and Execution (Log(P/E)) - Mission planning and unit readiness.

Sapient Corporation, an Arlington software company, developed the CLC2S program. The same company is also involved in the production of the prototype system for C2 in the sea base.

Joint Command and Control (JC2)

There are several constraints on the logistics C2 system for the sea base. One is that it must be consistent with the DoD Joint Command and Control (JC2) Capability program. This in the future will be DoD's main information technology system. It will replace the Global Command and Control System (GCCS) family of systems (GCCS-FOS) currently in use and contain some Service-specific functionality. It is seen as a solution to interoperability problems. It will have a top down design in contrast to developing in an evolutionary pattern as the Internet did. The JROC approved the JC2 Operational Requirements Document (ORD) in August 2003. The analysis of alternatives for JC2 was released in 2005 as the result of a joint effort by CNA and the Institute for Defense Analyses (IDA) [22]. JC2 achieved Milestone A on January 27, 2006 [23], and the Defense Information Systems Agency (DISA), designated as the Lead Component, is moving forward with initiating the program.

Distributive Collaborative Command and Control (DCC2)

As a way to begin to begin the process of creating the logistics C2 system for the sea base, ONR initiated in 2003 the development of Naval Logistics Command and Control (NLC2). The characteristics desired for this system were:

- Navy logistics battle space management and theater-wide awareness
- Logistics supply chain management and control
- Sea base operational control
- Provision of decision tools to support planning and rapid replanning
- Interoperability with naval applications, in particular GCCS-M.

In 2004, NLC2 evolved into Distributive Collaborative Command and Control (DCC2). Development of this program, which is designed as a template for the logistics C2 system that will be needed for the sea base, was contracted to Sapient Corporation, the developer of CLC2S. Sapient states that its vision for the program is to develop a FORCEnet C2 capability by 2015 that supports seabasing by providing actionable logistics information and user-defined situational awareness while enabling collaborative and iterative COA development, assessment and execution at the speed of battle by naval, joint and coalition warfighting decision-makers [24]. There is a disconnect between the 2015 date in the above vision statement and Sapient's metric (stated later) to field a FORCEnet capability by 2007. We assume that it intends to have the beginnings of the system in place by 2007 and the fully functioning system ready by 2015. There are currently programmatic difficulties with the program and it is unclear at this time whether options on the program will be picked up.

Through a FORCEnet backbone, DCC2 will access the information stored in individual naval logistics systems. It will use these data in its three modules: planning and execution, readiness assessment, and forecasting and simulation. Each operator will be able to compose an individual version of the user-defined operating picture (UDOP). Once defined, the UDOPs may be shared with others to facilitate the collaborative planning process. Figure 9 shows the architecture Sapient has developed for DCC2. In order to alleviate any interoperability issues, DCC2 must be designed so that its architecture is compatible with the structure prescribed by JC2. It must also be interoperable with the USMC CLC2S logistics system. Figure 10 shows the architectural alignment of the various systems. The current GCCS-FOS will be

replaced over the next decade by JC2, and DCC2 must be compatible with JC2 and interoperable with CLC2S.

Figure 9. Logical architecture for DCC2

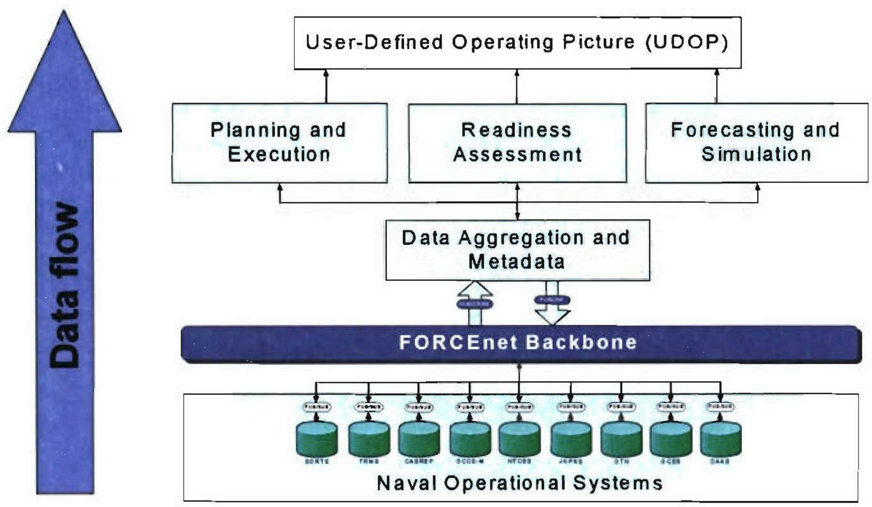
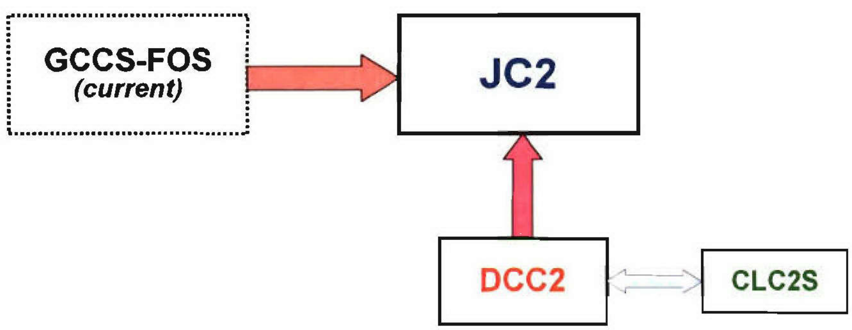


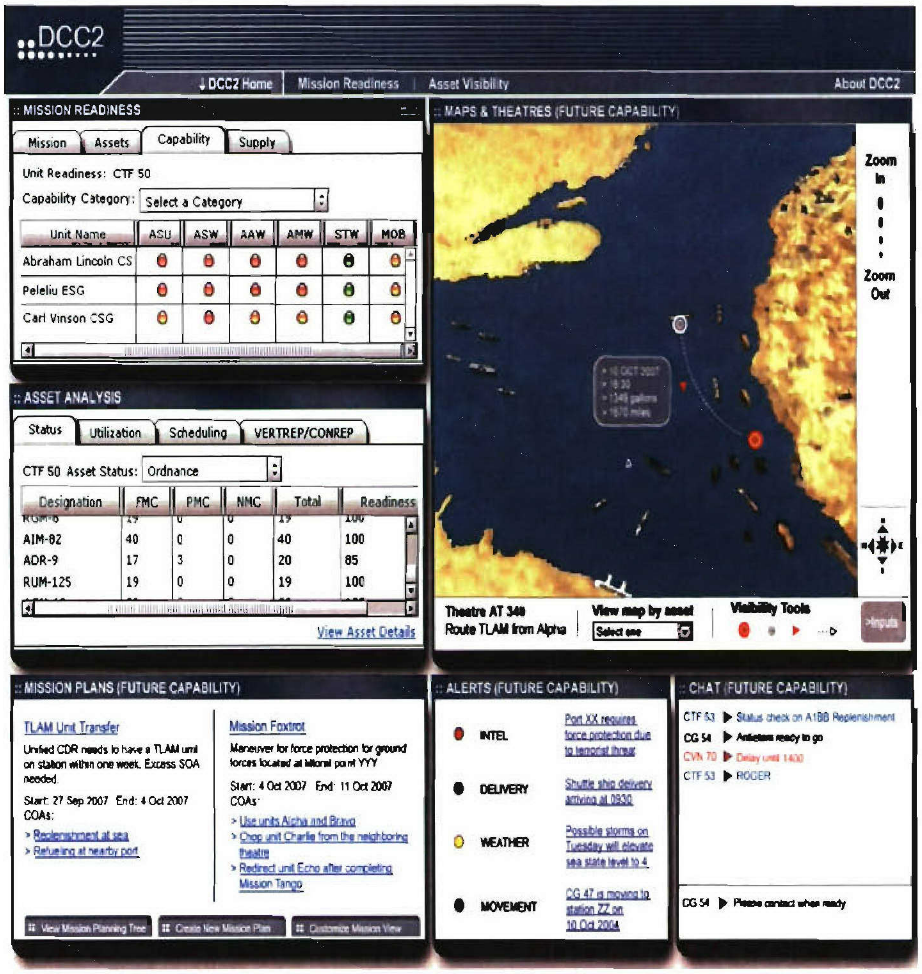
Figure 10. C2 architectures



Since DCC2 is in an early stage of development, not all functions have been activated. Sapient has adopted a strategy of using workshops with subject matter experts to define the capabilities that need to be included in DCC2, and then using rapid, iterative releases in a spiral development program to gain feedback from the operational and logistics communities as to the utility and shortcomings of each prototype.

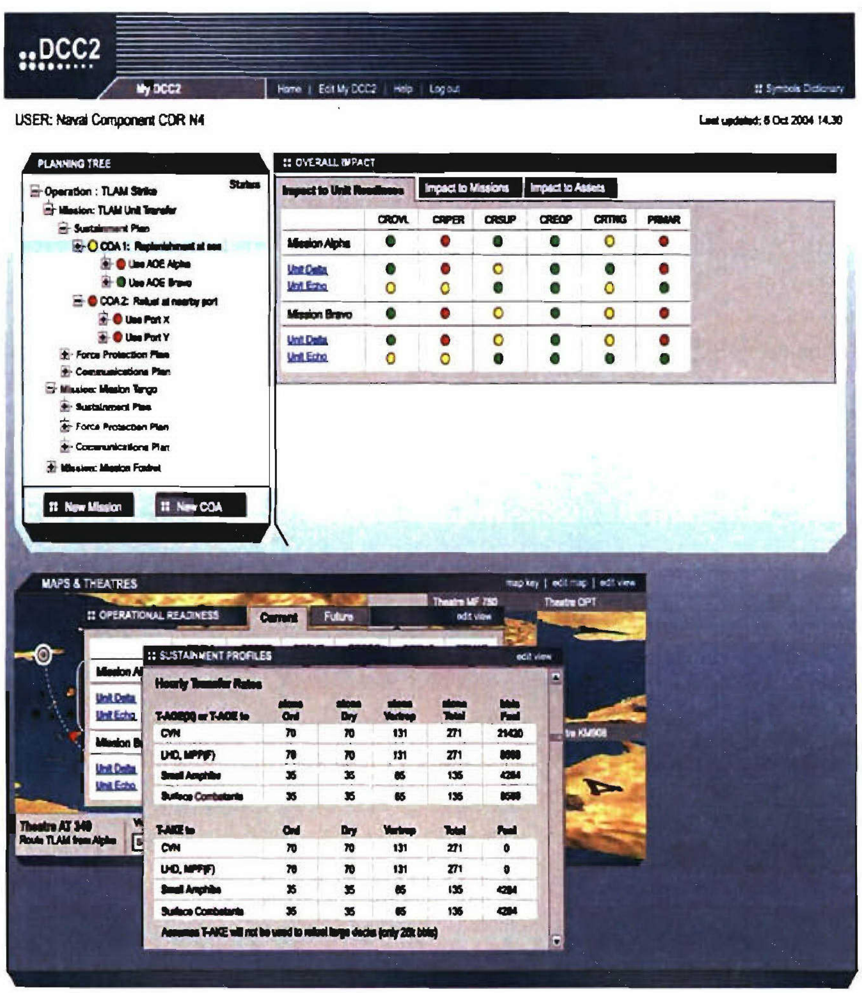
Figures 11 and 12 show sample screen captures from the DCC2 program. In figure 11, the upper left region shows the mission readiness

Figure 11. Screen capture of page display from DCC2 prototype



of each unit in each warfare area. The user can not only check the level of readiness of the individual unit but also view data for other units and logistics systems. The next panel shows the analysis of the assets available, and that can give a view of their time-phased availability. The other aspects of the display include a map (selected according to the UDOP), a planning section, an area showing alerts, and a window for chat, which is becoming the chief method operators use to communicate. The UDOP as selected by the operator can be shared with other DCC2 users.

Figure 12. Screen capture of page display from DCC2 prototype



The screen capture in figure 12 displays the time-phased development of various COAs and facilitates adaptation of the COAs in response to real-time operational constraints. The last section of this page shows how logistics is integrated into the planning process. Planned transfers of materials among the sea base ships are tabulated

In developing DCC2, Sapient has defined a set of five capabilities that the system will include:

- User-Defined Operational Picture - Provides a customizable tool that visually integrates planning data, asset status, and unit readiness for current and future operations
- Planning and Execution - Improves coordination by developing integrated plans across multiple levels of command and monitoring the execution of those plans
- Readiness Assessment - Provides increased visibility into the readiness of units and current and future asset visibility across the theater
- Forecasting and Simulation - Enhances decision-making by forecasting future readiness, performing what-if scenarios, and permitting virtual rehearsal
- Data Aggregation - Integrates into other naval, joint, and coalition systems and collates real-time logistics data from across the battle group.

There must be defined metrics to determine whether measurable progress is being made toward reaching the goals of the program. Sapient has defined a set of six metrics for this purpose.

- Become a fielded FORCEnet capability by 2007
- Reduce the dependency on overseas staging areas and support by 20% by 2010
- Increase the number of collaboratively developed mission and logistics plans by 50% by 2010

- Reduce the number of personnel hours (currently about 140 staff hours per day) required to produce a daily commander's brief by 80% by 2008

- Improve the timeliness of logistics data accessed by commanders by 50% by 2010

- Reduce the number of unanticipated conflicts between operational and logistics plans by 50% by 2010

DCC2 will be fielded in a distributed manner. By this, we mean that the program will reside on the server at each participating unit rather than all of the software being hosted at a central location. Using this procedure means that there is not a limit on how many units may participate in the sharing of data and in the collaborative planning process. Thus DCC2 should be able to support even the large sea base that would be required for a contingency requiring an MCO. The concepts in the design of DCC2 are sound and the metrics seem achievable.

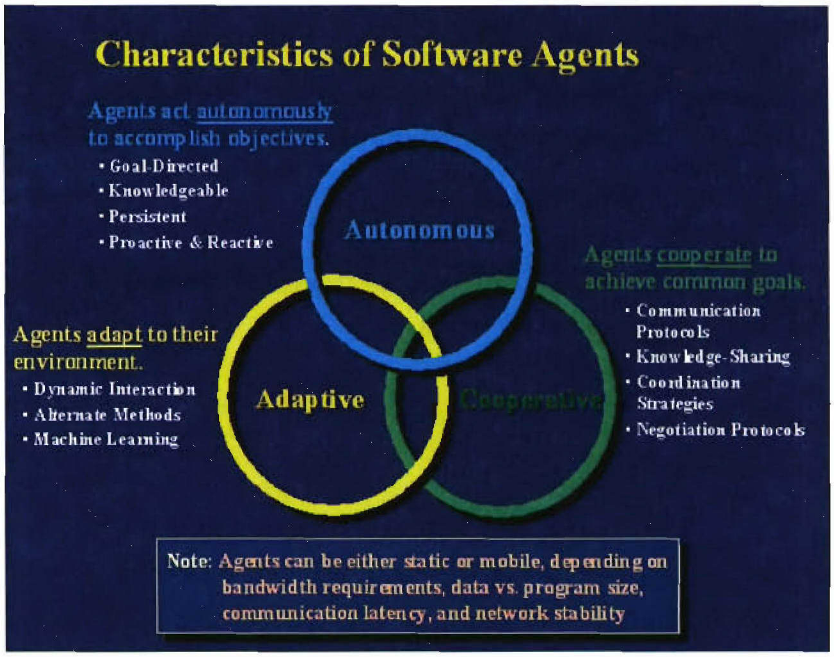
Intelligent agents

The C2 system that manages logistics for the sea base will be extremely complex. It will need to reach many decisions in near real-time to handle supervision of delivery of supplies and it must also be able to function in the collaborative planning realm. The volume of the information that must be handled and the speed with which COAs must be recommended will exceed the capabilities of the available Naval officers, especially if manning is reduced as planned. There must be automatic decision aids to help sift through the possibilities and select the most promising of those for consideration by the decision makers. These decision support tools are referred to as intelligent agents.

An intelligent agent is a software program that can perform many functions for a human computer user by applying a certain amount of reasoning [25]. Groups of intelligent agents can together form an "agent society," an information system composed of networked intelligent agents. The field of research into the development and use of intelligent agents is an active one. Figure 13 [26] shows some proper-

ties of intelligent agents. We discuss a few examples of existing intelligent agents.

Figure 13. Properties of intelligent agents



Control of Agent-Based Systems (CoABS)

Control of Agent Based Systems (CoABS) is a Defense Advanced Research Projects Agency (DARPA) project with the following mission [27]:

> To develop and demonstrate techniques to safely control, coordinate, and manage large systems of autonomous software agents. The Control of Agent-Based Systems (CoABS) program will develop and evaluate a wide variety of alternative agent control and coordination strategies to determine the most effective strategies for achieving the benefits of agent-based systems, while assuring that self-organizing agent systems will maintain acceptable performance and security protections.

According to the project director, CoABS addresses the crucial military need of assembling disparate information systems into a coherently interoperating whole without redesign of the systems and the need of including non-DoD governmental systems, coalition partners' systems, and commercial off-the-shelf (COTS) and open source systems not built to governmental standards [28]. In short, the goal is to achieve a comprehensive and scalable approach to software agent interoperability that can enable the warfighter to access the information that is needed to make decisions and can act as a force multiplier as the sizes of military forces are drawn down.

One of the products arising from CoABS is the CoABS Grid (referred to as the "Grid"), which is arguably the most successful and widely used infrastructure to date for the large-scale integration of heterogeneous agent systems [29,30]. The Grid provides the middleware that enables dynamic interoperability of distributed, heterogeneous objects, services, and multi-agent systems. The Grid has been licensed to over 400 organizations and applied to enable large scale interoperability among complex heterogeneous command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) systems. We give three examples of such applications:

- The Grid has been used to provide high-connectivity among airborne sensor platforms in the Multi-Agent System for Mission and Situational Awareness Management (MASAM) to increase situational awareness in the airborne battlespace [29].
- The Grid has been adopted in systems for monitoring high interest vessels (HIV) by Second and Sixth Fleets [30].
- The Grid has been used to construct Cooperating Agents for Specific Tasks (CAST), an implementation that supports the time critical strike (TCS) warfighting function and which has been used in five separate Fleet Battle Experiments (FBEs) [31].

Reusable Environment for Task Structures Intelligent Network Agents (RETSINA)

Reusable Environment for Task Structures Intelligent Network Agents (RETSINA) is an open multi-agent system (MAS) that supports communities of heterogeneous agents [32]. The development of RETSINA was supported by ONR. The infrastructure and its agents have been applied to many domains, including financial portfolio management, personalized web information management, book-buying auctions, logistics planning in military operations, and wireless, mobile communications.

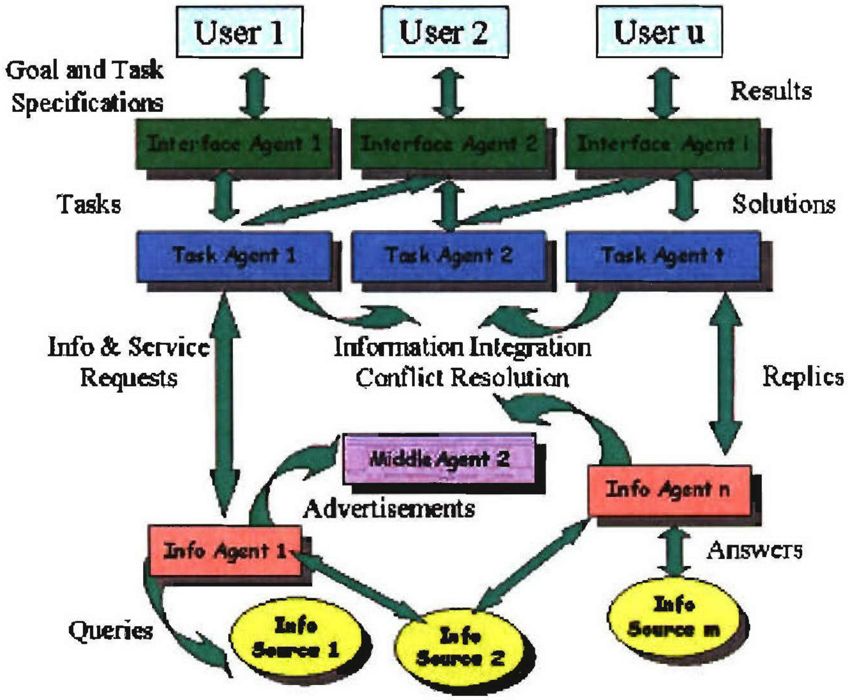
The RETSINA functional architecture consists of four basic agent types:

- Interface agents that interact with users, receive user input, and display results
- Task agents that help users perform tasks, formulate problem-solving plans and carry out these plans by coordinating and exchanging information with other software agents
- Information agents that provide intelligent access to a heterogeneous collection of information sources
- Middle agents that help match agents that request services with agents that provide services.

In the MAS, the agents operate asynchronously and collaborate with each other and the user. After a user has posed a question, the agents actively seek out information and integrate the information gathering process with problem solving and decision support.

Figure 14 shows a graphical representation of the RETSINA MAS.

Figure 14. RETSINA MAS infrastructure



Logistics applications

Efforts have been made to develop intelligent agents that are specifically directed toward the logistics process. One of these, described in a 1997 forecast on the future of information and management technology within the Department of the Navy [33], is Real-Time Logistics Management (RTLM), defined as the near-real-time ability to plan, execute, monitor, and replan the availability of people, equipment, units, and supplies to support military operations. Among the technologies identified as most important to logistics management are autonomous smart agents for information collection; interactive, integrated simulations; and process optimization. This forecast predicts that most of the RTLM information functions will be highly

automated by 2035, the time frame we have been asked to consider for the far-future sea base.

Another logistics effort using intelligent agents has been defined by the U. S. Army Logistics Integration Agency (USALIA). The problem it addresses is that many decision support aids were developed in isolation and they do not interact with one another. To link these systems effectively will require the design and development of an open systems architecture generic enough to integrate the different subsystems of a distributed system. The proposed solution is the Distributed Intelligent Agents for Logistics (DIAL) in which intelligent agents manage the components of the system by decomposing the overall logistics problem into smaller more tractable segments and assigning these segments to the appropriate intelligent agents that then work together to generate a logistics plan [34]. The intelligent agents structure is superimposed on top of the individual models to allow the models to communicate and collaborate among themselves as the logistics plan is being developed. The realization of such a system is deemed to be integral to the Revolution in Military Logistics, Army Vision 2010, and Joint Vision 2010.

The goal of the UltraLog project, sponsored by DARPA, is to build an extremely survivable, agent-based logistics planning and execution information system for the modern battlefield [25]. When presented with an operations plan (OPLAN), the UltraLog system responds by building a logistics support plan containing two primary components: detailed time-phased force and deployment data (TPFDD) and a sustainment plan [35]. The TPFDD provides detailed information about what gets moved, conveyances, routes, and start and stop times. The sustainment plan provides information on projected demand, refill, inventory on hand, and potential inventory shortfalls. The scenarios tested simulated units of the Army's V Corps fighting a 180-day major regional contingency in Southwest Asia. In all, the scenario involved hundreds of military units, 28,000 major end items, and 33,000 personnel.

UltraLog has showed its capability in producing the TPFDD and the sustainment plan in a timely manner. The system was also tested for its replanning capability when OPLAN alterations caused significant

replanning and it was tested for its robustness and security when under cyber attack and/or kinetic attack.

Robustness refers to the ability to maintain functionality when parts of the system are disabled. The robustness of UltraLog was assessed by running more than 170 experiments in which the system lost some capability. The injuries inflicted on the system included degrading CPU resources by up to 75%, degrading memory by up to 75%, cutting communication links among units, degrading bandwidth, and removing the logistics capability of support units. The robustness requirement is that the system can sustain a 45% loss in infrastructure and have less than a 20% reduction in capability with less than a 30% reduction in performance. In the 170 experiments, UltraLog has shown "remarkable robustness" in continuing to provide useful logistics information with its capabilities degraded.

Security of the system is a measure of its resistance to various sorts of cyber attacks. These can be categorized by the attacker's intent:

- To destroy system infrastructure or data
- To intercept sensitive information
- To corrupt or manipulate logistics information
- To disrupt service.

As a group, the UltraLog security defenses provided significant protection from cyber attack. All defended the system completely or nearly completely from the attempted attacks. Significant portions of the threat envelope were effectively secured.

The UltraLog system has shown its ability to produce a TPFDD in well under an hour and to rework logistics plans to accommodate significant OPLAN changes in less than 30 minutes. It has the robustness to continue to produce useful results with significant damage to it resources, and it can mount effective defenses against cyber attack

Sample S&RL intelligent agent system

ONR sponsored a wargame in August 2005 to consider the use of S&RL in seabasing [36]. At that wargame, the Operations and Logis-

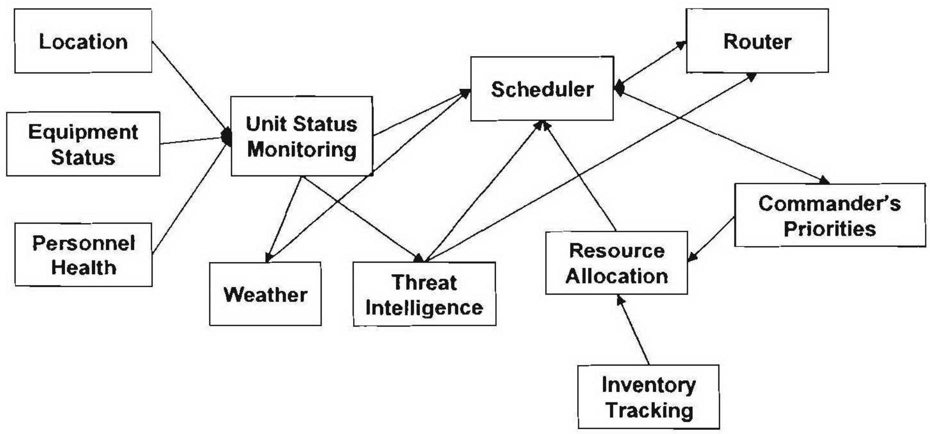
tics (Ops/Log) Concept Cell developed a notional scenario to illustrate how intelligent agents can contribute to implementation of the S&RL concept. The scenario envisioned troops operating ashore with logistical support from a sea base. The troops ashore suffered a breakdown in one piece of equipment and nearly simultaneously received a signal from a condition based maintenance (CBM) embedded sensor indicating that a second, identical piece of equipment would likely fail within the next four to eight hours. The intelligent agent had the task of collecting information and suggesting to the local commander various courses of action that could be taken in response to this situation.

Figure 15 illustrates the information that needs to be considered in developing response options. First, there must be a determination as to whether the parts needed to repair the equipment exist on the sea base and where the repair parts are stored. This requires TAV of the sea base inventory. Suppose that only a single replacement is available, and the prediction is that very shortly two pieces of equipment will not be functional. A decision must be made as to which component is the more critical and how available resources will be allocated. That will depend on the current status of each unit (personnel health, location, whether they are currently engaged with hostile forces, etc.) and what operations are planned for the units in the immediate future. Those plans in turn depend on the commander's intent——what the commander intends to accomplish in the near term—and what equipment is more important to carrying out that intent. The issue of creating software code that precisely reflects the commander's intent is one that must be solved for the intelligent agent to accurately choose the optimal COAs.

Once the decision has been made as to which unit will receive the replacement, a plan must be developed for accomplishing the repair. The parts, the technicians who can make the repair, and the tools that they need must be located and transported to the location of the piece of equipment. These items and personnel may be on different vessels within the sea base so transfers among sea base vessels by air or surface connectors may be required. The possible need for a security force to protect the repair technicians must also be evaluated based on the current unit condition. Transportation for all necessary per-

sonnel and materials must be planned, considering available connectors, weather conditions, and threats that might be encountered along the possible routes. The intelligent agent must be capable of considering all relevant information and providing COAs, which the command staff can then consider and decide upon. All of these functions could be performed manually, but the time required for human decision-making in all these areas will be incompatible with the pace of activity needed to support a force ashore in a dynamic battle situation. Although the intelligent agent may not be structured exactly as shown in figure 15, this example does illustrate the range of factors that must be considered as plans are made and refined.

Figure 15. Schematic of intelligent agent operations



Bandwidth

One of the implicit assumptions in the plan to move to network-centric warfare is that the amount of available bandwidth will be sufficient to support all of the communications that are planned for transfer of information from one node to another. We examine available information to determine whether this assumption is justified. This analysis reviews both the projected supply and the projected demand for bandwidth for the Navy and for the U. S. Army and compares that demand to supply. The Navy analysis focuses on communi-

cations relayed via satellites because those are the communication links available to the sea base units when they are not within line-of-sight of each other. Information on other types of bandwidth is included in the Army discussion.

Navy bandwidth supply

The satellites used during Operation Iraqi Freedom (OIF) were the following [37]:

- Defense Satellite Communications System (DSCS) - A military satellite constellation placed in geosynchronous orbit to provide high-volume, secure voice and data communications. The constellation consists of five primary and six residual satellites providing total earth coverage.
- Extremely High Frequency Medium Data Rate (EHF MDR) - A cross-linked constellation of four satellites carrying MILSTAR II payloads to provide worldwide coverage to mobile units.
- Commercial Wideband Satellite Program (CWSP) - A system providing high-data-rate capabilities such as video teleconferencing, telemedicine and data image transfer.
- International Maritime Satellite (INMARSAT) - A global satellite system used by independent service providers to offer a range of voice and multimedia communications for customers on the move or in remote locations.

The assumption that the Navy will automatically be allocated 25–30% of the available bandwidth as one of the three Services is not justified. Bandwidth allocations are made based on strategic and tactical priorities. In OIF, the fleet received only 3–9% of the satellite resources available in theater. This percentage could vary in future conflicts, depending on which forces have the more significant role in the conflict.

There are plans to field new satellite constellations in the future to increase wide band connectivity. The currently planned programs are the following:

- Wideband Gapfiller Satellite (WGS) will support communications in both the X-band and Ka-band. There are plans to deploy three satellites (with two more proposed) in geosynchronous orbit, with the first launch in FY06. WGS is intended to replace the aging DSCS constellation and will also support a global broadcast system (GBS) payload.

- Advanced Extremely High Frequency (AEHF) will replace the existing Extremely High Frequency (EHF) constellation and support worldwide, protected communications. Three satellites are planned with an option for two more if they are needed and funding is available. The Air Force now favors not exercising the option [38]. After several delays, the first satellite is now scheduled to be launched in 2008.

- Transformational Satellite (TSAT) will provide improved, survivable, jam-resistant, worldwide, secure and general purpose communications as part of an independent but interoperable set of space-based systems that will support National Aeronautics and Space Administration (NASA), DoD, and the intelligence community [39]. The plan is to launch five satellites, the first two with reduced technology and the last three with full capacity. A recent restructuring will delay the first launch until 2014 [38].

The important property for assessing whether bandwidth is sufficient is not global capability but how much bandwidth can be provided to specific regions likely to be the site of future conflicts. An analysis published in 2005 [37] estimated the available bandwidth from military satellites in a theater of operations in 2010 and in 2015. These estimates were based on the programs as then conceived; the actual amounts available may be less based on changes in the programs (delays and decreases in scope) since that time. Table 5 shows the estimated available bandwidth. The estimates include assumptions about the coverage areas of the satellites and how many can view a specific

area, the bandwidth available in proposed systems, and the projected degradation rates of current operating systems

Table 5. Estimated bandwidth from military satellites

Satellite system	Number of satellites with coverage	2010		2015	
		Bandwidth per satellite (Mbps)	Total bandwidth (Mbps)	Bandwidth per satellite (Mbps)	Total bandwidth (Mbps)
DSCS	2	190	380	75	150
EHF MDR	1	34	34	26	26
WGS	2	2,400	4,800	2,400	4,800
AEHF	2	210	420	210	420
TSAT	2			2,100	4,200
Total			5,634		9,596

Not all of this bandwidth will be available to the Navy. Based on the experience in OIF, we can estimate the allocations that may be expected in a future conflict. During OIF, the Navy received 3% of the DSCS bandwidth and 9% of the EHF MDR bandwidth. We will adopt these percentages as minimum and maximum values, with the midpoint of 6% as the most likely. This allows us to estimate the bandwidth allocation for a future naval task force and these results are in table 6.

Table 6. Predicted bandwidth supply

Time frame	Total bandwidth (Mbps)	Fleet allocation	Task force bandwidth (Mbps)
2010	5,634	Minimum: 3%	169
		Most likely: 6%	338
		Maximum: 9%	507
2015	9,569	Minimum: 3%	288
		Most likely: 6%	576
		Maximum: 9%	864

The important quantity for naval operations is the effective bandwidth, the amount available after accounting for communications overhead. Routing and encryption overhead plus retransmissions reduce the amount of bandwidth available to send or receive useful information. Routing overhead runs between 4 and 20% of the available bandwidth; the encryption overhead is between 18 and 67%. The number of bytes that must be retransmitted is between 3 and 10%. Applying these factors to the values in table 6 gives us the effective bandwidth available as reported in table 7.

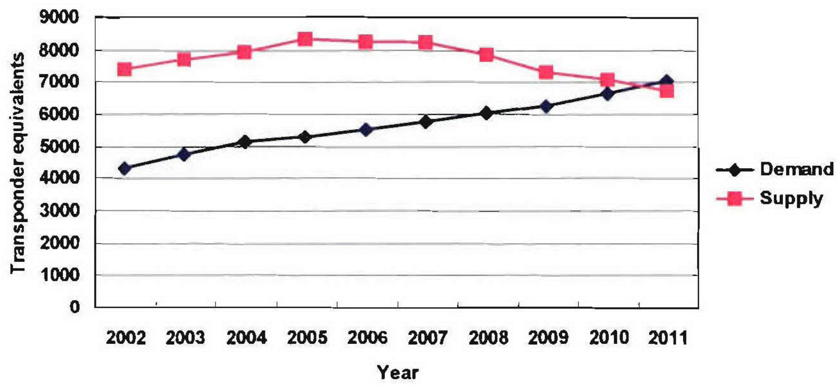
Table 7. Predicted effective bandwidth supply

Time frame	Task force allocation (Mbps)	Effective bandwidth (Mbps)
2010	Minimum: 169	Minimum: 40
	Most likely: 338	Most likely: 107
	Maximum: 507	Maximum: 387
2015	Minimum: 288	Minimum: 68
	Most likely: 576	Most likely: 183
	Maximum: 864	Maximum: 659

The tables above refer to military satellite bandwidth. During Operation Enduring Freedom (OEF) in Afghanistan, 60% of satellite capacity was provided by commercial satellites [40]. In OIF, DoD also leased space on commercial satellites. This option may be foreclosed in the future. In the 1990s with the high tech boom in full swing, commercial vendors increased their capacity, anticipating an increase in demand that has not yet developed. An unprecedented 980 transponder units were launched in 2002, up from only 376 in 2001. This resulted in the excess capacity that was available for OIF. In the future, market forces will create better alignment between supply and demand. In a recent report, Futron Corporation, a technology management consulting firm, forecast demand and supply for commercial satellite bandwidth through 2011 [40]. Results are shown in

figure 16. By 2011, demand will exceed supply, leaving no excess capability for the military to lease.

Figure 16. Forecast of commercial satellite bandwidth supply and demand



Navy bandwidth demand

The projections for the Navy bandwidth demand are based on the Satellite Database (SDB). The SDB is a forecast of the bandwidth capacity that each type of ship will require in the near-, mid-, and long-term. The forecasts in the past have not always proved to be reliable due both to mistakes such as summing the transmit and receive values and to misestimates about how much would be needed. Based on the SDB, total bandwidth requirements were calculated for task forces of two sizes - a 94-ship task force, corresponding to OIF size, and a 45-ship task force, the size that might respond to a Taiwan scenario. The values listed as minimum demands have a correction factor included that assumes that overestimates in the SDB are the same percentage as those previously observed in the SDB. The maximum values take the SDB at face value after correcting for obvious errors, such as summing transmit and receive bandwidths. Table 8

gives minimum and maximum values for the effective bandwidth demands and restates the bandwidth supply values from table 7.

Table 8. Effective bandwidth supply and demand values for naval task forces

Time frame	Options	Effective bandwidth supply (Mbps)	Effective bandwidth demand (Mbps)	
			45 ships	94 ships
2010	Minimum	40	40	88
	Most likely	107		
	Maximum	387	295	681
2015	Minimum	68	85	201
	Most likely	183		
	Maximum	659	622	1,472

Table 8 shows that the most likely value for bandwidth supply will meet the minimum demand estimate for both sizes of task force in 2010, but the supply could fall well short if the demand tends to the high side. For the 2015 time frame, the most likely supply is below the minimum demand for the larger task force. If the SDB is taken at face value, the demand for bandwidth will exceed what is likely to be provided by about a factor of three in a Taiwan scenario and by a factor of six in an OIF scenario in 2010. Even allowing for uncertainties in these estimates, the results show that bandwidth will be a valuable commodity in the future and that it is not obvious that the Navy will have all it needs.

Army bandwidth

The picture for bandwidth supply and demand in the Army is more difficult to discern. In 2003, the Congressional Budget Office (CBO) issued a report on bandwidth in the Army [41]. The report shows that, although there has been an explosive growth in the amount of information that now must be transmitted as well as a shift in the type of information, the Army's communication system still retains the emphasis on verbal communication that was appropriate for an earlier time. The problem was exacerbated by the Army's digitization ini-

tiative, which led to a significant increase in the demand for bandwidth. The CBO study concludes that the current bandwidth demand at all levels is larger than the supply. At some levels the shortfall is as much as an order of magnitude. This situation is projected to continue through and after 2010, in spite of the planned investment of $20 billion in new communications equipment

The Army infrastructure for communication support has historically depended on wireless radio transmissions, and high bandwidth messaging depending on physical links has not been available. Radio networks are ideal for mobile forces whose current location may not be known precisely. Satellite communications are used for some levels of command (brigade and above), but these systems are not available to lower level units. The CBO compared the effective bandwidth available at the operations desks of various tactical command levels with the estimates of total demand at those levels. We show the results for 2003 in table 9. The color coding indicates the balance between supply and demand. Light yellow represents that supply and demand match within a factor of three. Red shows that demand exceeds supply by at least an order of magnitude. Intermediate values are shown by magenta. For the brigade level, two values are given: *up* represents communications with higher levels of command and *down* with lower levels. The bandwidth bottleneck occurs at the brigade to lower level commands.

Table 9. Effective bandwidth supply versus peak demand in 2003 by command level

Command level	Bandwidth supply (kilobits /s)	Peak bandwidth demand (kilobits/s)	Relative supply versus peak demand
Corps	2,550	3,000-10,000	1:1 to 4
Division	533	2,500-4,000	1:5 to 8
Brigade	533 (up)	800-1,000	1:1.5 to 3 (up)
	37 (down)		1:20 to 30 (down)
Battalion	37	500-750	1:10 to 20
Company	15	30-100	1:2 to 6
Platoon	15	10-30	1:0.5 to 2
Squad/vehicle	1.7	3-10	1:2 to 6

A similar assessment of the balance between supply and demand was performed for the Army of 2010. By that time, there will have been incremental growth in existing programs and the introduction of some new programs, thereby increasing the supply of bandwidth. Simultaneously, demand is projected to double every two to five years across all levels of command. The CBO used the more conservative end of that range in its calculations. An additional factor is that the planned transformation of the Army will lead to increased use of unmanned aerial vehicles (UAVs). This will generate a sizeable demand for additional bandwidth, the size of which will depend, to some extent, on how the intelligence from the UAVs is distributed. Table 10 is a summary table showing the supply versus demand situation predicted for 2010. The color coding is as before, with green indicating that supply exceeds demand. The results in 2010 differ somewhat from the 2003 results in that the bottleneck has shifted from the brigade to the corps level, but it is no less severe.

Table 10. Effective bandwidth supply versus peak demand in 2010 by command level

Command level	Relative supply versus peak demand (S:D)
Corps	1:10 to 30
Division	1:10 to 30
Brigade	1:3 to 10 (up)
	1:5 to 15 (down)
Battalion	1:1.5 to 3
Company	1 to 4:1
Platoon	4 to 10:1
Squad/vehicle	7 to 20:1

Bandwidth summary

Managing the logistics system for the sea base and the supported troops ashore will require a robust C2 system that can handle an as yet unquantified but presumably large communication demand. We have examined the availability of bandwidth to transmit the information necessary to manage the logistics of the sea base and the troops

ashore. We see that, based on the scheduled deployment of satellites and the predicted demands by naval forces included in the SDB, there may be a severe mismatch between the supply and the demand for bandwidth in 2015. This mismatch does not account for the demands of a new, information intensive logistics system, an increased demand that will only worsen the situation. It also appears that there is a bottleneck in Army communications due to the excess of demand over supply and that this will persist until and beyond 2010. There will also not be commercial capacity available for lease by DoD because the supply and demand factors in the commercial realm will come into balance. These factors combine to indicate that the adoption of the network-centric operations of the sea base as envisioned may be threatened by a lack of bandwidth, and this issue should be further analyzed.

Data security

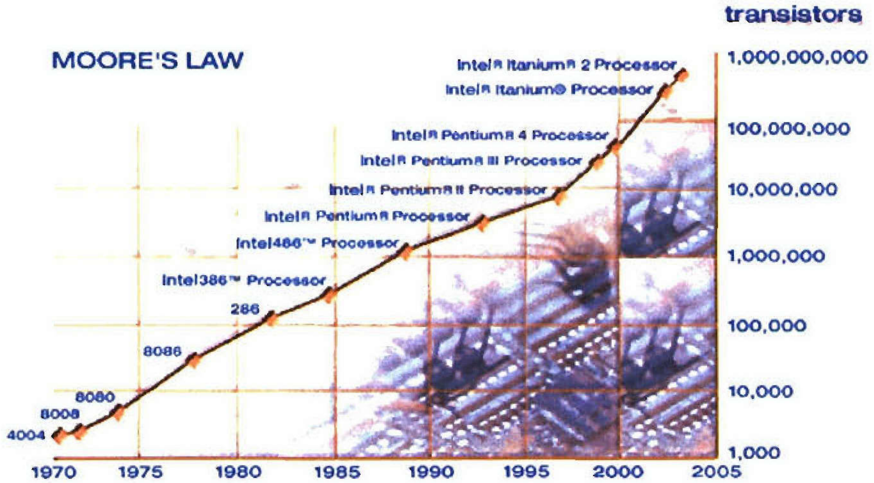
Some logistics data are transmitted on unclassified systems such as the Non-Classified Internet Protocol Router Network (NIPRNET) while others are transmitted on classified systems such as Secret Internet Protocol Router Network (SIPRNET). All the data must be merged to form a complete common operational picture (COP). Because of the sensitivity or classification of the logistics data, precautions must be taken to protect them from unauthorized interception. Advances in information technology have brought new approaches in data encryption to the edge of technical feasibility. One particular approach, quantum cryptography, relies on physical principles to facilitate data transfer without danger of illicit interception of the data. Although we are aware of the intent of having the Natioanl Security Agency (NSA) develop a packet encryption technique to protect the data being transmitted, we are including the following section on data security as an invitation to ONR to consider it for inclusion as an item in its S&T portfolio.

The advances in technology and information processing capabilities over the past few decades have been nothing less than breathtaking. In 1965, Gordon Moore proposed his version of what has become known as Moore's Law. In his article in the journal *Electronics* [42], he stated:

> The complexity for minimum component costs has increased at a rate of roughly a factor of two per year... Certainly over the short term this rate can be expected to continue, if not to increase. Over the longer term, the rate of increase is a bit more uncertain, although there is no reason to believe it will not remain nearly constant for at least 10 years.

Although it refers explicitly to the cost of component manufacturing, this prediction has been transformed into a prediction that computing power will double every year. (In 1975, Moore amended the time frame to every 24 months [43].) The predicted exponential growth of computing power has been sustained for far longer than anyone initially predicted. In 2002, the 27th doubling of computer power brought us the advent of the billion-transistor computer chip [44]. This growth is shown graphically in figure17 [45].

Figure 17. Exponential doubling of computing power



Each time it seemed that limitations of a particular technology would stop the increase, a new technology emerged; mechanical computing machines gave way to vacuum tubes, followed by transistors and silicon-based integrated circuits. What will be the next change in technology? It seems that optical computing may still be a long way from

implementation [46]. Optical interconnects are closer to reality and using light as a means of data transmission while protecting data security is a technology that has been demonstrated commercially.

As we said previously, the amount of data that must be transferred for the management of the logistics of the data base is substantial and the data transfer rate by optical means is low if we employ single photon techniques. These data rates will not support the encryption and transfer of all the data needed, but they are sufficient for the transfer of the key needed to decrypt the data transferred by conventional means. This capability for secure key transfer is the basis of quantum cryptography. This method is an extension of public-key cryptography, which is often used to distribute the secret keys for encrypting and decoding full length messages. Previously, the security of public-key cryptography has relied on a difficult mathematical procedure such as factorization of large numbers. With the availability of more and more powerful computers, these methods have become vulnerable to being broken. Quantum cryptography introduces an unbreakable method of encryption.

Quantum cryptography is based on the Heisenberg Uncertainty Principle. Mathematically, the Uncertainty Principle can be stated as:

$$\Delta x \Delta p \geq \frac{h}{4\pi},$$

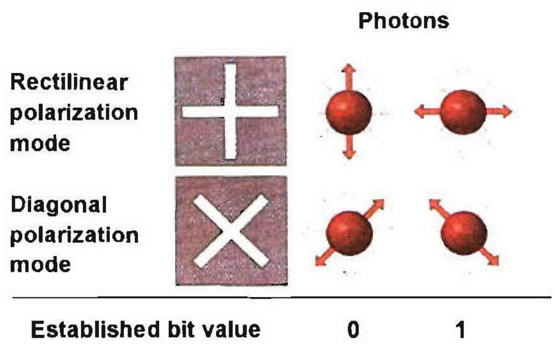
where x represents position, p represents momentum and h is Planck's constant. The relationship can be used to state the minimum uncertainty of any two conjugate variables. Conceptually, the Uncertainty Principle means that any measurement of the state of a system alters the state of the system. This principle makes it impossible to break the encrypted transfer of the key because the act of intercepting the information encoded into single photons will change the state of the photons. This change can be detected and the photons intercepted will not be used in the key exchange.

There are two different approaches to the application of quantum cryptography, both based on the fact that measuring a system disturbs

the system. One is based on the use of entangled photons and was developed by Artur Ekert [47]. The second, the one we discuss here, was proposed by Bennett and Brassard in 1984 [48]. It describes a method for quantum key distribution. The descriptions of the method that we present come from [49] and [50]; the figures are derived from those in the article by Stix [49].

This method requires that the sender and receiver communicate by the transmission of single photons. The polarization of the photon is determined by the sender. This polarization may be either rectilinear (vertical or horizontal) or diagonal (45 degrees to the right or left of vertical). In either polarization mode, the opposing positions of the photons represent either a digital 0 or a digital 1. The assignments for the two modes of polarization are illustrated in figure 18. In the rectilinear polarization, 0 correlates to vertical and 1 to horizontal. In the diagonal mode, 0 is 45 degrees to the right of vertical and 1 is 45 degrees to the left of vertical.

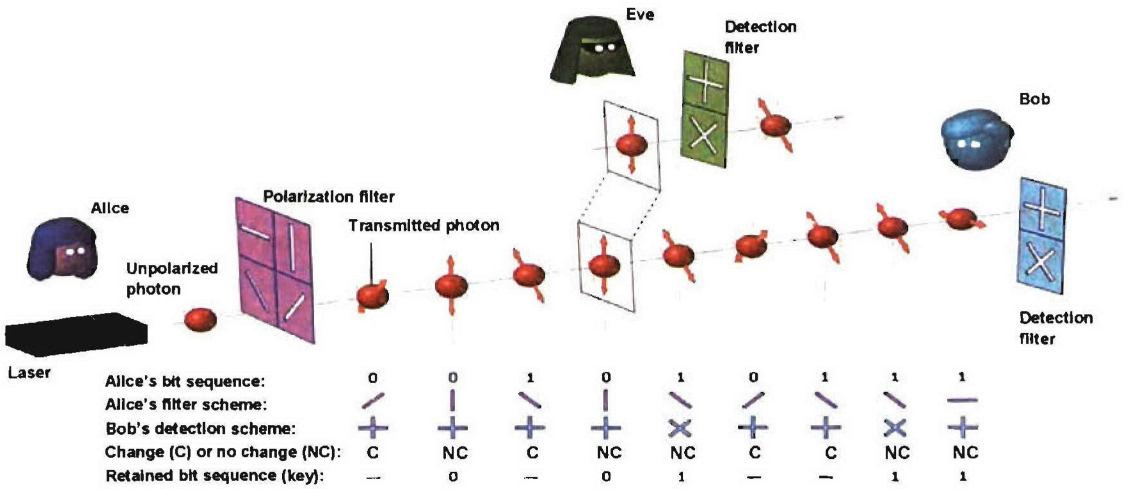
Figure 18. Bit values for photon polarizations



The sender of the message (conventionally referred to as Alice) randomly chooses for each photon whether to send it in the rectilinear mode or in the diagonal mode. The receiver (conventionally referred to as Bob) makes a similar random decision as to the setting of the

polarizer at the receiving end. Bob cannot measure the bits in both modes because the Heisenberg Uncertainty Principle states that two conjugate variables cannot be exactly measured simultaneously. Only the bits for which the polarization set by Bob is the same as that selected by Alice are guaranteed to retain their proper value. Other photons will have their polarization altered. After transmission, Alice and Bob communicate on an unsecured channel. Bob tells Alice the setting he chose for each photon, but not the value he measured. Alice then tells Bob which of the photons were measured correctly, i.e., those that were observed with the correct polarization mode and were therefore unaltered. This scheme is represented in figure 19.

Figure 19. Quantum cryptography detection scheme



Alice uses a laser to produce single, unpolarized photons. She then randomly selects a polarizer to encode information. In this example, the first photon is diagonally polarized at 45 degrees to the vertical, indicating a binary 0 (see figure 18). Bob has set his detector for the first photon to rectilinear polarization. Since this is a different polarization, the photon interacts with the polarizer and the polarization is scrambled. This is represented by the "C" for "Change" in the

fourth row of the table (NC represents "No Change"). Five of the nine photons in figure 19 pass through the detection polarizer without being altered. Alice tells Bob which photons are unchanged based on his telling her the settings he used for the detection polarizers. This process of determining which bits are unchanged is known as the sifting of the key.

What is the effect of attempted eavesdropping by Eve? If an eavesdropper attempts to intercept a photon, she must choose which polarization to measure. If she chooses incorrectly, she alters the photon's polarization. On average, measurements of half the photons will be made with the incorrect polarization and will alter the sequence shared by Alice and Bob. Alice and Bob can check for the presence of errors by comparing the values of their sequence of bits using classical communication channels. The bits revealed during the error checking process are then discarded.

Further processing steps are taken to ensure that the key transfer is secure. Any process has some intrinsic error rate; errors occur that are not due to interception of photons by Eve. Classical error correction routines can correct the errors and allow Alice and Bob to estimate how much information Eve may have obtained about the key. Privacy amplification is a cryptographic form of error correction. Consider as an illustration a two-bit key shared by Alice and Bob and assume that it is 01 [50]. Also assume that Eve knows the first bit is 0. A putative privacy amplification protocol could consist of adding the two bits without carry, which would yield 1, and using the result as the key. Eve does not know the second bit. For her, the value could be either 00, giving a sum of 0, or 01, yielding 1. Thus she lacks any information about the key. Privacy amplification can be applied to either the Bennett-Brassard or the Ekert (entangled photons) protocol, although it can be applied directly at the quantum level and is more efficient for the latter.

Do commercial systems using these techniques currently exist? The Ekert protocol using quantum entanglement (famously referred to by Einstein as "spooky action at a distance") [49] has not yet been commercialized. On the other hand, id Quantique of Geneva Switzerland, MagiQ Technologies of New York City, and QinetiQ of Farns-

borough, England have operating commercial products based on the Bennett-Brassard method. These systems have been shown to operate over lengths of optical fiber up to 150 km. This arrangement of course is not applicable to the sea base because the seabase is not physically connected to any communication networks. There are, however, efforts underway to prove the feasibility of sending quantum keys through the air. Transmission over a path length of 23 km was demonstrated in 2003 [51]. One of the authors stated:

> Using slightly bigger telescopes, optimized filters and anti-reflection coatings we expect to be able to build a system which is stable up to 34 dB of loss and capable of maximum ranges exceeding 1600 km, suitable for satellite key upload.

The development of the capability to reach satellites in low earth orbit (LEO) would mean that the technique can be used for secure communications with the sea base.

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Summary and recommendations

We analyzed the structure of the sea base that might be required to respond to a number of possible contingencies. The sea bases needed to respond to all types and scales of contingencies require a common set of capabilities, i.e., the necessary capabilities are independent of the size of the sea base. This report focuses on the logistics command and control (C2) functions that must be in place for the sea base to operate efficiently.

We began the study by reviewing the documents available on seabasing. These include documents such as the Joint Integrating Concept documentation and the Defense Science Board, Naval Research Advisory Committee, and Naval Studies Board reviews on seabasing. They also include the Naval Postgraduate School analytical study of the sea base as it is expected to operate in 2015 under its Baseline Architecture and under alternative concepts of operation. We also looked at reviews of critical technologies identified by the National Shipbuilding Research Program focused on the strike-up/strike-down process and by the Littoral Warfare Systems Product Area Directors on critical technologies for the 2015 sea base. These studies helped to direct our efforts in examining the sea base and the capabilities that it needs to possess.

Although the Navy has a logistics system that is able to meet its current requirements, the logistics management system for the sea base will require a new design. It must conform to the Navy's transition to network-centric warfare. It must use the emerging information technology innovations to increase its capacity and capabilities and allow support of both the personnel on the sea base and the supported troops ashore. There should be serious consideration given to the implementation of the principles of Sense and Respond Logistics. This is a forward-looking concept adopting the precepts of the post-transformation Navy and using the new characteristics enabled by the information technology revolution. A template for the logistics C2

system, Distributive Collaborative Command and Control or DCC2, is undergoing a spiral development process as a prototype for the emerging system. This program appears to be progressing well and is receiving input from those who will need to operate the system in the future. The developers predict that they will have a fielded operational system by 2015, assuming that programmatic concerns are addressed.

Other issues need to be addressed as development of the C2 system proceeds. Attention should also be focused on research and development efforts in the area of intelligent agents. These decision aids will be crucial to the operation of the logistics C2 system for the sea base. There must be a careful, systematic assessment of the issue of bandwidth availability—whether there will be bottlenecks that will limit the amount of logistics and other information that can be transmitted to the platforms in the sea base. Since information from unclassified and secure sources must be combined to form the COP for operational planning and control, development of a quantum cryptography capability for satellite communications to ensure data security would be a fruitful area for ONR investment.

Glossary

AASLT	air assault
AB	advanced base
ACE	air combat element
AEHF	advanced extremely high frequency
AMC	Air Mobility Command
ASN RD&A	Assistant Secretary of the Navy (Research, Development and Acquisition)
ATT	advanced theater transport
BCT	brigade combat teams
BLA	baseline architecture
BLT	battalion landing team
C2	command and control
C4ISR	command, control, communications, computers, intelligence, surveillance, and reconnaissance
CASREP	casualty report
CAST	cooperating agents for specific tasks
CBM	condition-based maintenance
CBO	Congressional Budget Office
CE	command element
CLC2S	Common Logistics Command and Control System
CLF	combat logistics force
CNA	Center for Naval Analyses
COA	course of action
CoABS	control of agent-based systems
COI	critical operational issue
COIN	counterinsurgency operations
CONOPS	concept(s) of operations
CONUS	continental United States
COP	common operational picture

COTS	commercial off-the-shelf
CSG	carrier strike group
CSS	combat service support
CSSE	combat service support element
CSSOC	Combat Service Support Operations Center
CWSP	Commercial Wideband Satellite Program
DAAS	Defense Automated Addressing System
DARPA	Defense Advanced Research Projects Agency
DCC2	distributive collaborative command and control
DIAL	distributed intelligent agents for logistics
DISA	Defense Information Systems Agency
DoD	Department of Defense
DoN	Department of the Navy
DR	disaster relief
DSB	Defense Science Board
DSCS	Defense Satellite Communications System
ECS	Enhanced Combat Service Support Operations Center System
EHF	extremely high frequency
EHF MDR	extremely high frequency medium data rate
ESG	expeditionary strike group
FBE	fleet battle experiment
FLS	forward logistics site
FNC	future naval capability
FOC	full operational capability
FOS	family of systems
GBS	Global Broadcast System
GCCS	Global Command and Control System
GCCS-M	Global Command and Control System-Maritime
GCE	ground combat element
GCSS	Global Combat Support System
GIG	Global Information Grid
GSORTS	Global Status of Resources and Training System
GTN	Global Transportation Network
GWOT	Global War on Terror

HA	humanitarian assistance
HIV	high interest vessel
HLD/HLS	homeland defense/homeland security
HSAC	high speed assault connector
HSC	high speed connector
IDA	Institute for Defense Analyses
INMARSAT	International Maritime Satellite
IOC	initial operational capability
JC2	Joint Command and Control
JCIDS	Joint Capabilities Integration and Development System
JELo	joint expeditionary logistics
JFEO	joint forcible entry operations
JIC	Joint Integrating Concept
JMIC	joint molecular intermodal container
JMPS	Joint Mission Planning System
JOA	joint operations area
Joint ACCESS	joint amphibious combat cargo expeditionary support ship
JOPES	Joint Operations Planning and Execution System
JROC	Joint Requirements Oversight Council
JSF	joint strike fighter
LCAC	landing craft, air cushioned
LCS	littoral combat ship
LCU(R)	landing craft utility, replacement
LEO	low earth orbit
LHA(R)	landing helicopter assault replacement
LHD	landing helicopter dock
LMSR	large medium speed roll-on, roll-off ship
Log(P/E)	logistics planning and execution
MAGTF	Marine Air Ground Task Force
MAS	multi-agent system
MASAM	Multi-Agent System for Mission and Situational Awareness Management
MCO	major combat operation
MEB	Marine Expeditionary Brigade
MEF	Marine Expeditionary Force

MIO	Maritime Interdiction Operation
MLP	mobile landing platform
MOP	measure of performance
MPF	maritime prepositioning force
MPF(F)	maritime prepositioning force (future)
MPG	maritime prepositioning group
NASA	National Aeronautics and Space Administration
NAVMACS	Naval Modular Automated Communications System
NCW	network-centric warfare
NEO	noncombatant evacuation operation
NIPRNET	Non-Classified Internet Protocol Router Network
NLC2	Naval Logistics Command and Control
NPS	Naval Postgraduate School
NRAC	Naval Research Advisory Committee
NSA	National Security Agency
NSB	Naval Studies Board
NSDA	non-self-deploying aircraft
NSE	naval support element
NSOF	Navy Status of Forces
NTCSS	Naval Tactical Command Support System
OEF	Operation Enduring Freedom
OFT	Office of Force Transformation
OIF	Operation Iraqi Freedom
ONR	Office of Naval Research
OPLAN	operation plan
OPNAV N7	Deputy Chief of Naval Operations for Warfare Requirements and Programs
Ops/Log	operations and logistics
ORD	Operational Requirements Document
R&D	research and development
RTLM	real-time logistics management
RETSINA	reusable environment for task structures intelligent network agents
RFID	radio frequency identification
RO-RO	roll-on, roll-off

RRTS	Rapid Request Tracking System
RSLS	rapid strategic lift ship
S&RL	sense and respond logistics
S&T	science and technology
SAG	surface action group
SDB	satellite database
SEA-6	systems engineering and analysis cohort six
SECDEF	Secretary of Defense
SIPRNET	Secret Internet Protocol Router Network
SOF	special operations forces
SORTS	Status of Resources and Training System
SSGN	nuclear powered guided missile submarine
SSTOL	super-short takeoff and landing
STOL	short takeoff and landing
STOVL	short takeoff and vertical landing
SUSD	strike-up/strike-down
TAV	total asset visibility
TCS	time critical strike
TEU	20-foot equivalent unit
TPFDD	time-phased force and deployment data
TRMS	Type Commander Readiness Management System
TSAT	transformational satellite
UAV	unmanned aerial vehicle
UDOP	user-defined operating picture
UEx	unit of employment
USALIA	U.S. Army Logistics Integration Agency
USMC	United States Marine Corps
USTRANSCOM	United States Transportation Command
VTOL	vertical takeoff and landing
WebSked	web-based scheduling
WGS	Wideband Gapfiller Satellite

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